CY8C20xx6A/H

CapSense® Design Guide

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Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
Phone (USA): 880.858.1810
Phone (Intnl): 408.943.2600
http://www.cypress.com

Contents

1. Introduction

1.1 How to Use This Document

This document provides design guidance for the CapSense® CY8C20XX6A/H family of devices. It is intended for design engineers who are familiar with capacitive sensing technology and have chosen this specific family of devices for their applications. For a thorough treatment of CapSense technology, including in-depth discussions of theory of operation and complete product offering detail, refer to Getting Started with CapSense.

1.2 CY8C20xx6A/H CapSense Family Features

Cypress's CY8C20xx6A/H is a low-power, high-performance, programmable touch sensing family of devices that features:

- CapSense Successive Approximation, Electromagnetic Compatible (CSA_EMC) and CapSense Sigma Delta (CSD) sensing technology
- SmartSense™ Auto-Tuning
- Supports up to 33 capacitive buttons and 5 sliders
- 1.71- to 5.5-V operating voltage
- Up to 33 GPIOs
- Wide variety of packages: 16-pad QFN (3 × 3 × 0.6 mm) to 48-pad QFN (7 × 7 × 1.0 mm), 30-ball WLCSP (2.2 × 2.3 × 0.4 mm), and 48-pin SSOP
- I^2C, full speed USB, and SPI communication interfaces
- Up to 32 KB flash and 2 KB SRAM
- CY8C20xx6H with Haptic (tactile) feedback
- Additional peripherals:
  - ☐ 24-MHz Internal Main Oscillator (IMO)
  - ☐ Three 16-bit timers
  - ☐ 20 × 2 LCD interface
  - ☐ EEPROM emulation
  - ☐ 8- to 10-bit incremental ADC
  - ☐ Internal voltage reference
  - ☐ Two comparators

1.3 Document Revision History

Revision	Issue Date	Origin of Change	Description of Change
**	12/14/2010	ANBA	New Design Guide
*A	3/4/2011	BVI	Multiple chapter enhancements for content and reader clarity

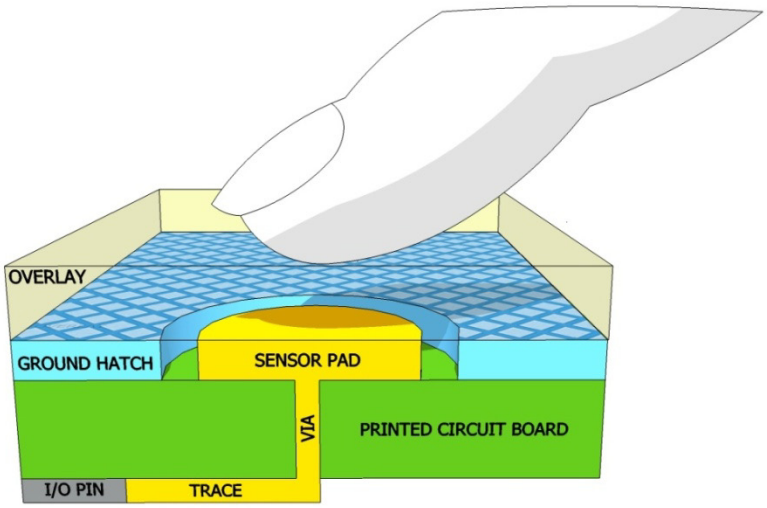
1.4 Document Conventions

Convention	Usage
`Courier New`	Displays file locations, user entered text, and source code: C:\ ...cd\icc\
Italics	Displays file names and reference documentation: Read about the *sourcefile.hex* file in the *PSoC Designer User Guide*.
[Bracketed, Bold]	Displays keyboard commands in procedures: [Enter] or [Ctrl] [C]
File > Open	Represents menu paths: File > Open > New Project
Bold	Displays commands, menu paths, and icon names in procedures: Click the **File** icon and then click **Open**.
Times New Roman	Displays an equation: 2 + 2 = 4
Text in gray boxes	Describes Cautions or unique functionality of the product.

2. CapSense Technology

2.1 CapSense Equivalent Model

Figure 2-1. CapSense System Equivalent Model



The capacitance measured by the CapSense controller is named C_X. When a finger is not on the sensor, C_X equals the parasitic capacitance of the system, C_P. When a finger touches the sensor surface, it forms a simple parallel plate capacitor through the overlay with the sensor pad. The result is called finger capacitance, C_F, and can be defined by the following equation.

$$C_F = \frac{\varepsilon_0 \varepsilon_r A}{D}$$ **Equation 1**

Where:

ε_0 = Free space permittivity

ε_r = Dielectric constant of overlay

A = Area of finger and sensor pad overlap

D = Overlay thickness

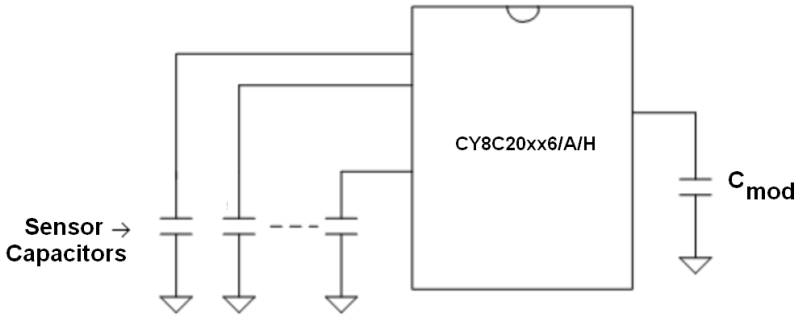
With a finger on the sensor pad, C_X equals the sum of C_P and C_F:

$$C_X = C_P + C_F$$ **Equation 2**

2.2 CapSense Capacitive Sensing Methods

The CY8C20xx6A/H device family measures sensor capacitance using either the CSD or CSA_EMC methods. Both of these methods require one additional capacitor, C_{MOD}. The recommended value for C_{MOD} is 2.2 nF with a minimum 5-V voltage rating and X7R or NPO types.

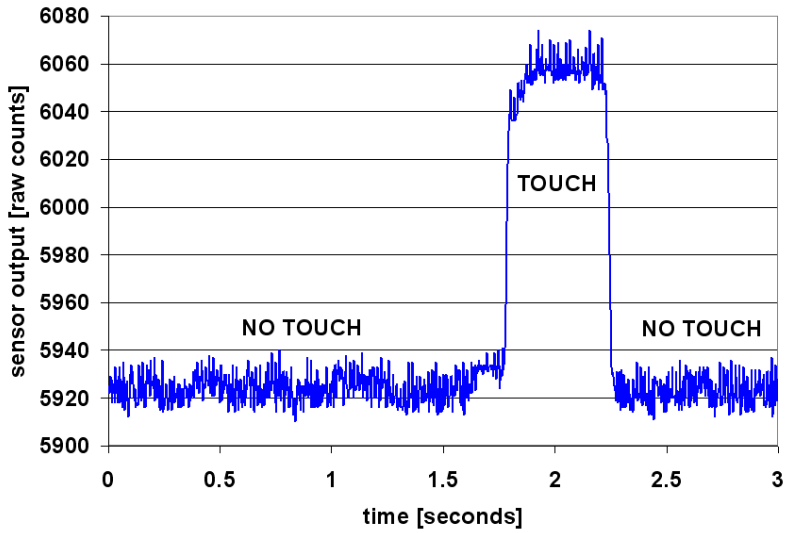
Figure 2-2. C_{MOD} Configuration



2.2.1 Capacitance Conversion

The CapSense algorithm converts the sensor capacitance into a digital count, called raw count. The raw count is interpreted as either a TOUCH or NO TOUCH state for the sensor. The numerical value of the raw count is the digital representation of the sensor capacitance. The sensitivity of a CapSense sensor is normally specified in units of counts-per-pF.

Figure 2-3. Output of Sensing Algorithm



2.2.2 CapSense with Sigma Delta Modulator (CSD)

Cypress's CSD method uses a switched-capacitor circuit on the front end of the system to convert the sensor capacitance to an equivalent resistor, as shown in Equation 3. A Sigma-Delta modulator converts the current measured through the resistor into a digital count. When a finger is on the sensor, the capacitance increases and the equivalent resistance decreases. This causes an increase in the current through the resistor, resulting in an increase in the digital count.

The CSD method requires one external component, C_{MOD}. This is an Integration capacitor that holds the charge transferred through the equivalent resistor.

Figure 2-4. CSD Block Diagram

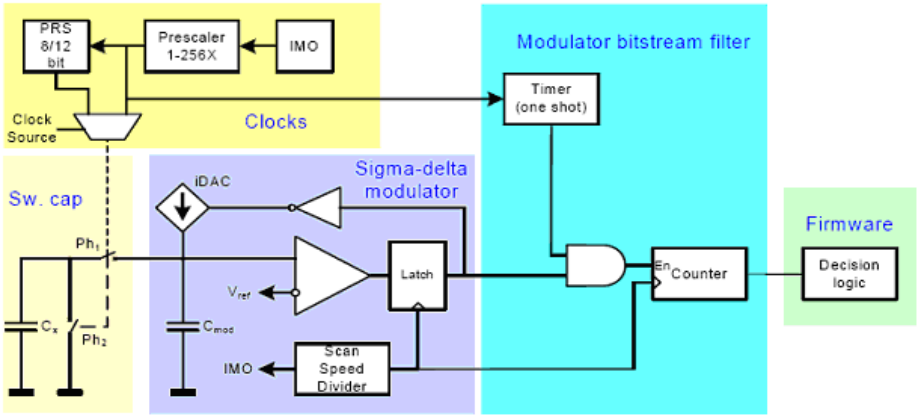
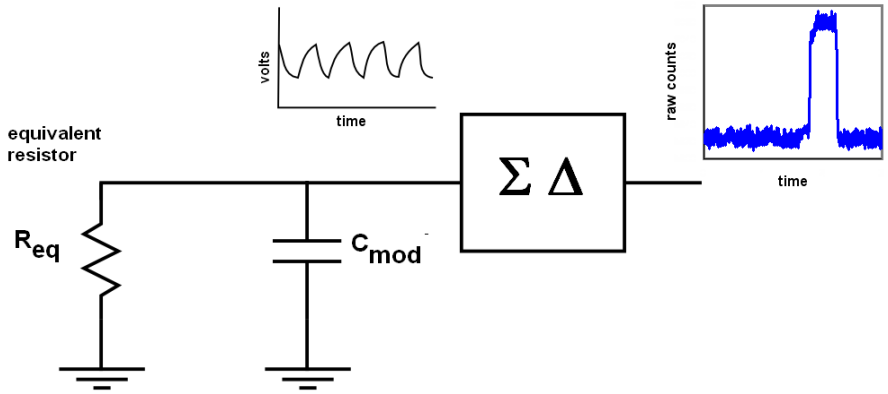


Figure 2-5. CSD Equivalent Circuit



$$R_{eq} = \frac{1}{f_{sw} \times C_P}$$ **Equation 3**

Where:

f_{SW} = switching frequency

C_P = sensor capacitance

For an in depth discussion of Cypress's CSD sensing method refer to PSoC® CY8C20x66, CY8C20x66A, CY8C20x46/96, CY8C20x46A/96A, CY8C20x36, CY8C20x36A Technical Reference Manual (TRM).

2.2.3 CapSense Successive Approximation Electromagnetic Compatible (CSA_EMC)

Cypress's CSA_EMC method also uses a switched-capacitor circuit on the front end of the system to convert the sensor capacitance to an equivalent resistor. An internal constant current source called the iDAC is calibrated with a successive approximation procedure until a preset voltage develops across the equivalent resistor. This baseline voltage is measured using a single-slope ADC. When a finger is on the sensor, the capacitance increases and the equivalent resistance decreases. This causes the voltage across the resistor to decrease and the ADC output to increase. This results in an increase in the digital count.

The CSA_EMC method requires one external component, C_{MOD}. This is an Integration capacitor that is used by the single-slope ADC.

Figure 2-6. Block Diagram of CSA_EMC

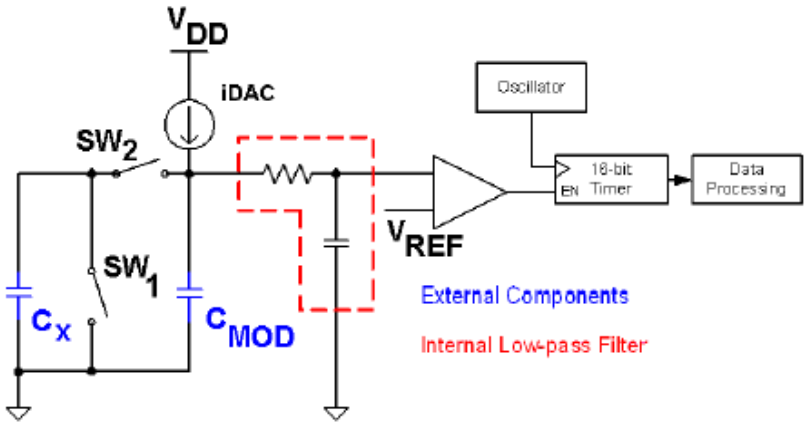
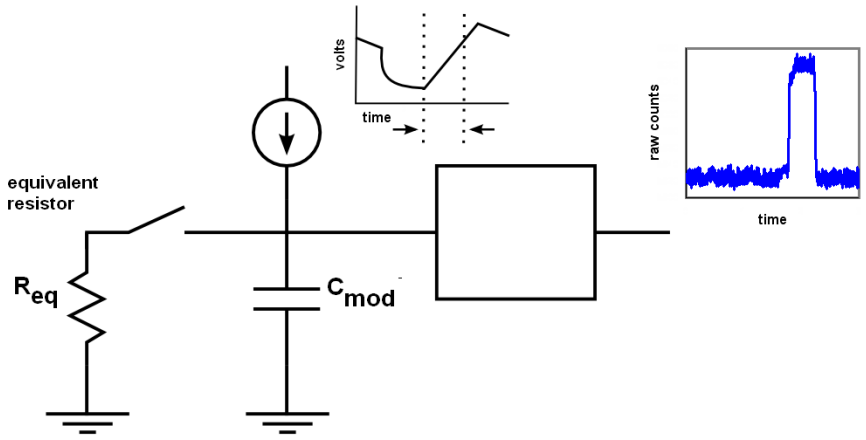


Figure 2-7. CSA_EMC Equivalent Circuit



The CSA_EMC CapSense algorithm has been enhanced to work well in the presence of RF interference. CSA_EMC is used in applications where CapSense is exposed to conducted interference, AC noise, and other noise sources that include inverters, transformers, and power supplies. CSA_EMC User Module Low-Level Parameters discusses this topic in detail.

For an in-depth discussion of Cypress's CSA_EMC sensing method, refer to PSoC® CY8C20x66, CY8C20x66A, CY8C20x46/96, CY8C20x46A/96A, CY8C20x36, CY8C20x36A Technical Reference Manual (TRM)

2.2.4 SmartSense™ Auto-Tuning

Tuning the touch sensing user interface is a critical step in ensuring proper system operation and a pleasant user experience. The typical design flow entails tuning the sensor interface in the initial design phase, during system integration, and finally production fine-tuning before the production ramp. Tuning is an iterative process and can be time consuming. SmartSense Auto-Tuning was developed to simplify the user interface development cycle. It is easy to use and significantly reduces the design cycle time by eliminating the tuning process throughout the entire product development cycle, from prototype to mass production. SmartSense tunes each CapSense sensor automatically at power up and then monitors and maintains optimum sensor performance during run time. This technology adapts for manufacturing variation in PCBs, overlays and noise generators such as LCD inverters, AC line noise, and switch-mode power supplies, and automatically tunes them out.

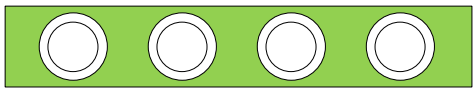
2.2.4.1 Process Variation

The SmartSense User Module (UM) for the CY8C20xx6A/H is designed to work with sensor parasitic capacitance in the range of 5 pF to 45 pF, (typical sensor C_P values are in the range of 10 pF to 20 pF). The sensitivity parameter for each sensor is set automatically, based on the characteristics of that particular sensor. This improves the yield in mass production, because consistent response is maintained from every sensor regardless of C_P variation between sensors within the specified range of 5 to 45 pF. Parasitic capacitance of the individual sensors can vary due to PCB layout, PCB manufacturing process variation, or with vendor-to-vendor PCB variation within a multisourced supply chain. The sensitivity of a sensor depends on its parasitic capacitance; higher C_P values will decrease the sensor sensitivity and result in decreased finger touch signal amplitude. In some cases, the change in C_P value will detune the system, resulting in less than optimum sensor performance (either too sensitive or not sensitive enough) or worst case, a nonoperational sensor. In either situation, you must retune the system, and in some cases requalify the UI subsystem. SmartSense Auto-Tuning solves these issues.

SmartSense Auto-Tuning makes platform designs possible. Imagine the capacitive touch sensing multimedia keys in a laptop computer; the spacing between the buttons depends on the size of the laptop and keyboard layout. In this example, the wide-screen machine has larger spacing between the buttons than a standard-screen model. More space between buttons means increased trace length between the sensor and the CapSense controller, which leads to higher parasitic capacitance of the sensor. This means that the parasitic capacitance of the CapSense buttons can be different in different models of the same platform design. Though the functionality of these buttons is the same for all of the laptop models, the sensors must be tuned for each model. SmartSense enables the system designer to do platform designs using the recommended best practices shown in section 3.7 PCB Layout in Getting Started with CapSense, knowing the tuning will be done efficiently and automatically.

Figure 2-8. Design of Laptop Multimedia Keys for a 21-inch Model

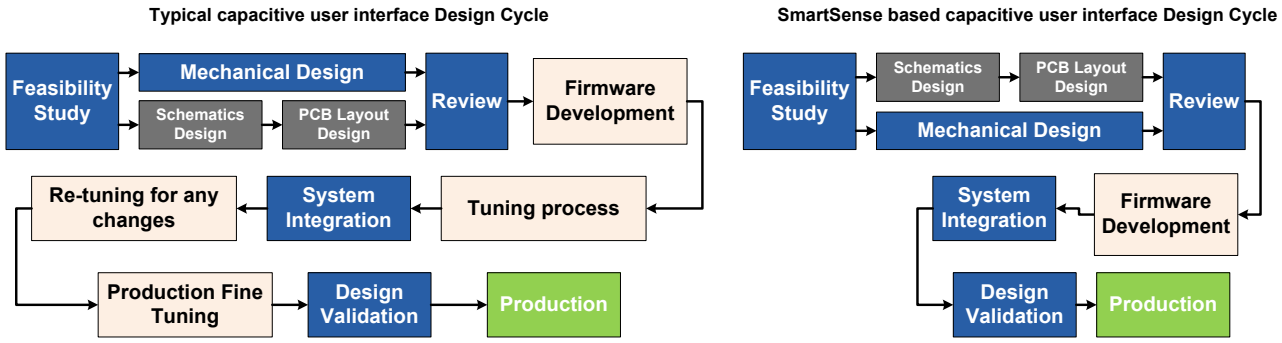
Figure 2-9. Design of Laptop Multimedia Keys for a 15-inch model with Identical Functionality and Button Size



2.2.4.2 Reduced Design Cycle Time

Usually, the most time consuming task for a capacitive sensor interface design is firmware development and sensor tuning. With a typical touch-sensing controller, the sensor must be retuned when the same design is ported to different models or when there are changes in the mechanical dimensions of the PCB or the sensor PCB layout. A design with SmartSense solves these challenges since it needs less firmware development effort, no tuning, and no retuning. This makes a typical design cycle much faster. Figure 2-10 compares the design cycles of a typical touch-sensing controller and a SmartSense-based design.

Figure 2-10. Typical Capacitive Interface Design Cycle Comparison



3. CapSense Design Tools

3.1 Overview

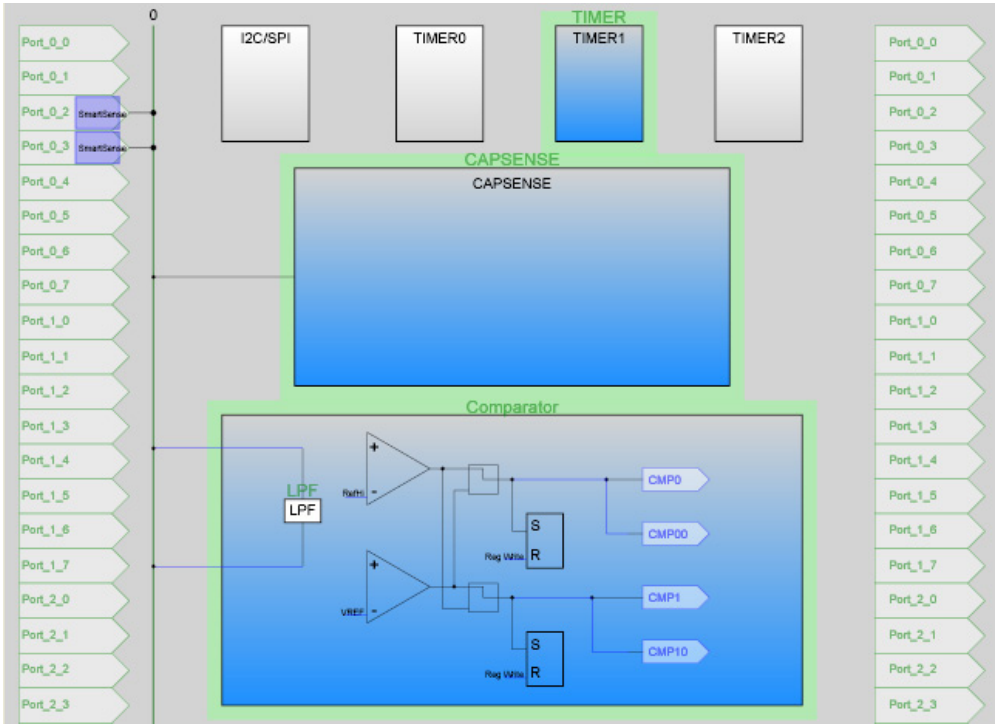
Cypress offers a full line of hardware and software tools for developing your CapSense capacitive touch sense application. A basic development system for the CY8C20xx6A/H family includes the following components. See Resources for ordering information.

3.1.1 PSoC Designer and User Modules

Cypress's exclusive integrated design environment, PSoC Designer, allows you to configure analog and digital blocks, develop firmware, and tune and debug your design. Applications are developed in a drag-and-drop design environment using a library of user modules. User modules are configured either through the Device Editor GUI or by writing into specific registers with firmware. PSoC Designer comes with a built-in C compiler and an embedded programmer. A pro compiler is available for complex designs.

CSD, CSA_EMC, and SmartSense User Modules implement an array of capacitive touch sensors using switched-capacitor circuitry, an analog multiplexer, a comparator, digital counting functions, and high-level software routines (APIs). User modules for other analog and digital peripherals are available to implement additional functionality such as I^2C, SPI, TX8, Timers, and PWMs.

Figure 3-1. PSoC Designer Device Editor



3.1.1.1 Getting Started with CapSense User Modules

To create a new CY8C20xx6A/H project in PSoC Designer:

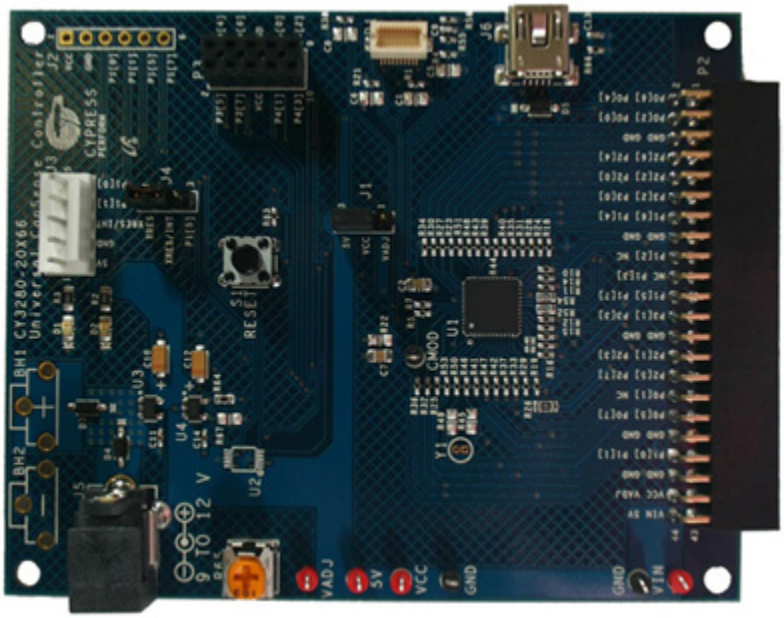
1. Select and place the CSD/CSA_EMC/SmartSense User Module.
2. Right click the user module to access the User Module Wizard.
3. Set button sensor count, slider configuration, pin assignments, and associations.
4. Set pins and global user module parameters.
5. Generate the application and switch to Application Editor.
6. Adapt sample code from the user module datasheet to implement buttons or sliders.

For a detailed step-by-step procedure for creating a PSoC Designer project and configuring the User Module Wizard, refer to the datasheet of the specific user module.

3.1.2 Universal CapSense Controller Kit

The Universal CY3280-20xx6 CapSense Controller Kit features predefined control circuitry and plug-in hardware to make prototyping and debugging easy. Programming and I^2C-to-USB Bridge hardware are including for tuning and data acquisition.

Figure 3-2. CY3280-20xx6 CapSense Controller Kit



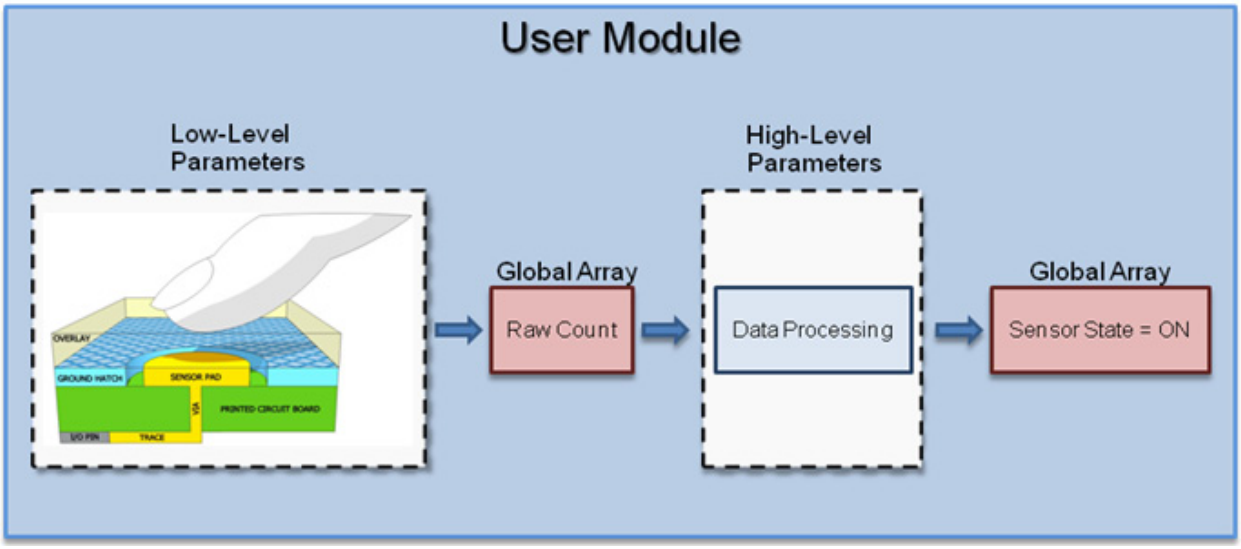
3.1.3 Universal CapSense Controller Module Board

Cypress's module boards feature a variety of sensors, LEDs, and interfaces to meet your application's needs

- CY3280-BSM Simple Button Module
- CY3280-BMM Matrix Button Module
- CY3280-SLM Linear Slider Module
- CY3280-SRM Radial Slider Module
- CY3280-BBM Universal CapSense Prototyping Module

3.2 User Module Overview

Figure 3-3. User Module Block Diagram



User modules contain an entire CapSense system, from physical sensing to data processing. The behavior of the user module is defined using a variety of parameters. These parameters affect different parts of the sensing system and can be separated into low-level and high-level parameters. The parameters communicate with one another using global arrays.

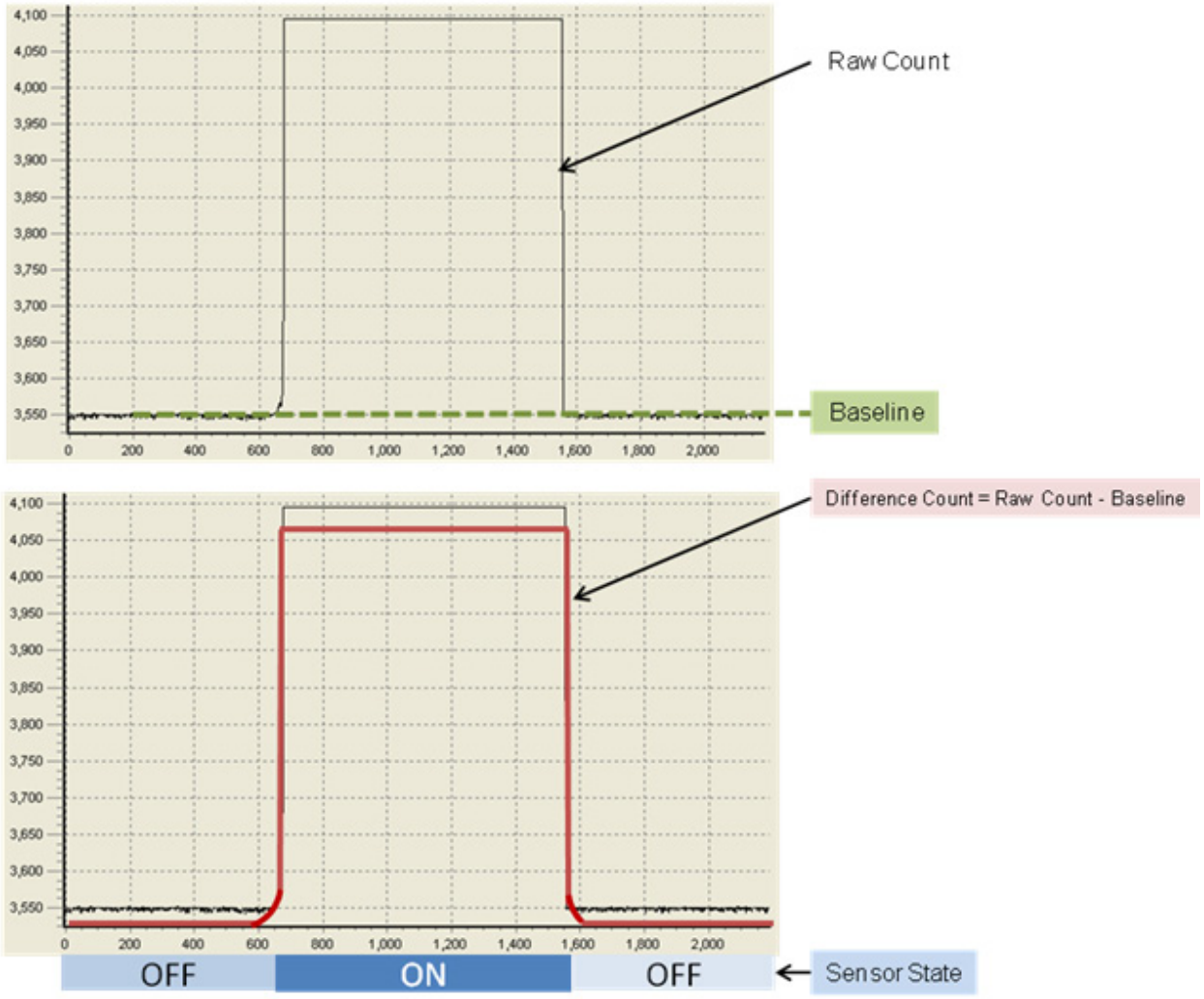
Low-level parameters define the behavior of the sensing method at the physical layer, and relate to the conversion from capacitance to Raw Count. These parameters include things like the iDAC's output range and settling time for the voltage across the C_{MOD}. Low-level parameters are unique to each type of sensing method and are described in CSD User Module Low-Level Parameters, CSA_EMC User Module Low-Level Parameters, and SmartSense User Module Parameters.

High-level parameters define the way taw counts are processed to produce information such as sensor ON/OFF state and estimated finger position on a slider. These parameters include things like debounce counts and noise thresholds. The high-level parameters are the same for all sensing methods and are described in High-Level Parameters.

3.3 CapSense User Module Global Arrays

Before studying CapSense User Module parameters, you need to know certain global arrays used by the CapSense system to ensure proper detection and operation in spite of environmental changes. These arrays should not be altered manually, but may be inspected for debugging purposes.

Figure 3-4. Global Parameters



3.3.1 Raw Count

The CapSense controller hardware measures the capacitance and provides the result in a digital form called Raw Count. The value of Raw Count increases as sensor capacitance increases.

Raw count values are stored in an integer array named *UMname*_waSnsResult[] where *UMname* is CSD, SmartSense, or CSA_EMC.

3.3.2 Baseline

The raw count values of a sensor vary gradually due to changes in the environment such as temperature and humidity. These gradual variations are compensated for with the baseline values. The baseline keeps track of gradual changes in raw count using a software algorithm. It is a low-pass filter that is less sensitive to sudden changes in the raw count. The baseline values provide the reference level for computing the difference counts.

Baseline values are stored in an integer array named *UMname*_waSnsBaseline[] where *UMname* is CSD, SmartSense, or CSA_EMC.

3.3.3 Difference Count

The difference count is the difference between the raw count and the baseline of the sensor. Usually, the difference count is zero when the sensor is inactive. When the sensor is touched, it causes the raw count to increase, and results in a positive difference count value.

Baseline values are stored in an integer array named *UMname*_waSnsDiff[] where *UMname* is CSD, SmartSense, or CSA_EMC.

3.3.4 Sensor State

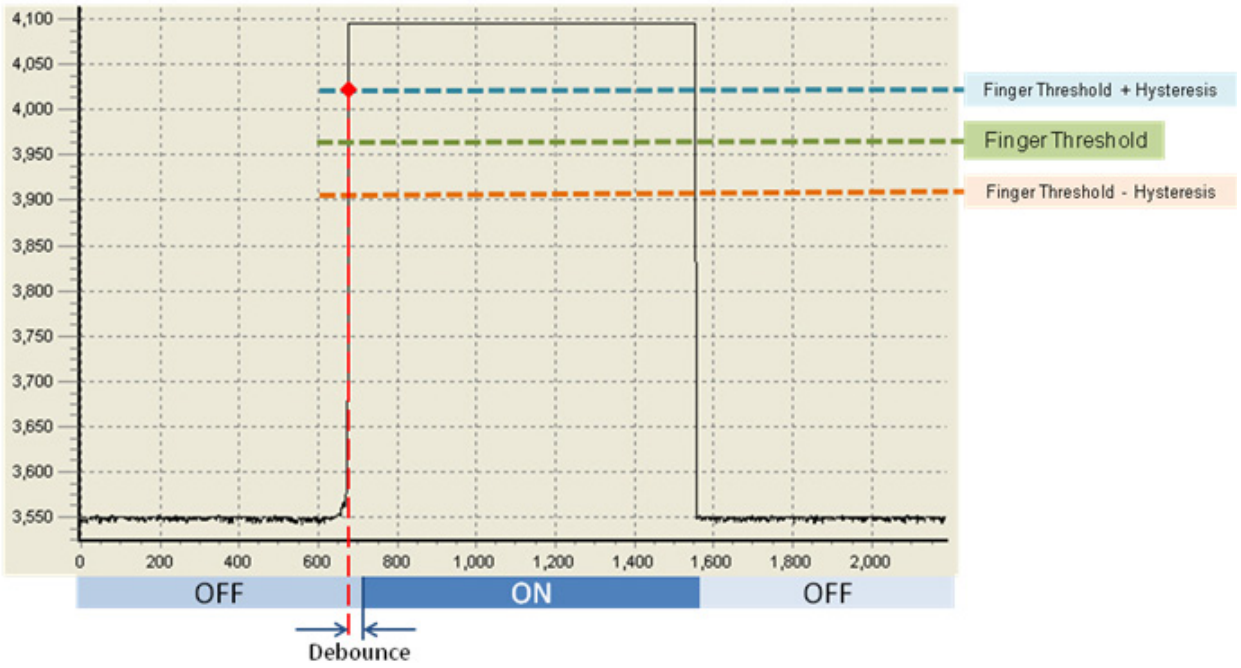
The state of each sensor is represented as 1 if the button is ON and 0 if the button is OFF.

The ON/OFF states for all of the sensors are stored in a byte array named *UMname*_baSnsOnMask[ ] where *UMname* is CSD, SmartSense, or CSA_EMC. Each array element can hold the ON/OFF state of eight sensors. *UMname*_baSnsOnMask[0] contains the masked bits for sensors 0 through 7. *UMname*_baSnsOnMask[1] contains the masked bits for sensors 8 through 15. This byte array contains as many elements as are necessary to include all of the sensors.

If any sensor is ON, the bIsAnySensorActive() function returns a 1. If all sensors are OFF, the bIsAnySensorActive() function returns a 0.

3.4 High-Level Parameters

Figure 3-5. High Level Parameters



$$if\ Difference\ Count \geq Finger\ Threshold\ + Hysteresis, \quad Sensor\ State = ON\ if\ Sample\ Count\ \geq Debounce$$
$$if\ Difference\ Count\ \leq Finger\ Threshold - Hysteresis, \quad Sensor\ State = OFF \qquad \textbf{Equation 4}$$

Where:

Sample Count = the number of samples measured above Finger Threshold + Hysteresis

3.4.1 Finger Threshold

The finger threshold parameter defines the sensitivity of the sensor to finger touches. It is used in conjunction with the Hysteresis parameter to determine the sensor state, as defined in Equation 4.

For individual sensors (not contained in a slider group) the Finger Threshold parameter is stored in a byte array named. baBtnFThreshold[] that contains as many elements as are necessary to include all sensors.

The SetDefaultFingerThresholds() function is used to set the thresholds to the default value set in the Device Editor.

Possible values are 5 to 255.

3.4.2 Hysteresis

The Hysteresis parameter is used in conjunction with the finger threshold to determine sensor state, as defined in Equation 4. Hysteresis adds immunity to noisy transitions. This is a debounce feature of a button. The touch state stays off until the difference counts are a little higher than the finger threshold. The touch state stays on until the difference counts are a little lower than the noise threshold. This prevents the touch/no touch state machine from triggering if the difference counts are very noisy and are halfway between noise and finger thresholds.

Possible values are 0 to 255. The Hysteresis parameter setting must be lower than the Finger Threshold parameter setting.

3.4.3 Debounce

This Debounce parameter adds a counter to the sensor transition from OFF to ON. For the sensor to transition from OFF to ON, the difference count value must stay above the finger threshold plus hysteresis level for the number of samples specified.

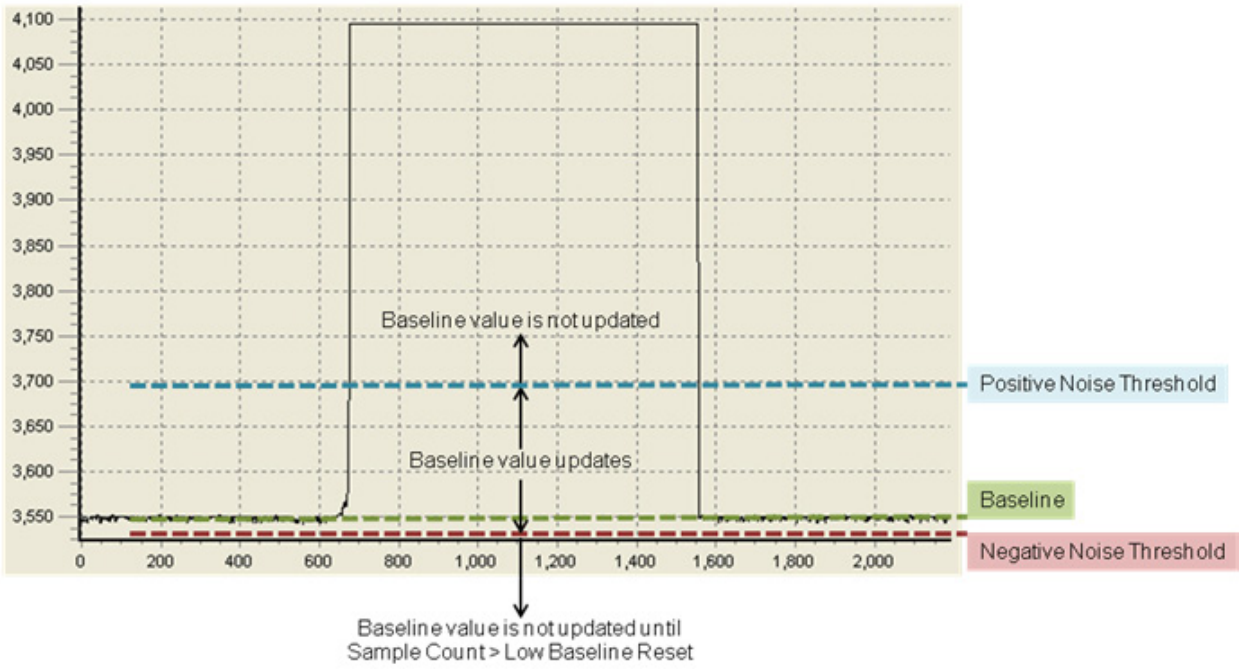
Possible values are 1 to 255. A setting of 1 provides no debouncing.

3.4.4 Noise Threshold

For individual sensors, the Noise Threshold parameter sets the upper raw count limit for updating the baseline value. For slider sensors, it sets the lower raw count limit for counting results in the centroid calculation.

Possible values are 3 to 255. The noise threshold value should never be set to higher than Finger Threshold minus Hysteresis value for proper operation of the user module.

Figure 3-6. Noise and Baseline Update Parameters



3.4.5 Baseline Update Threshold

When the raw count value is above the current baseline and the difference count is below the noise threshold, the difference between the current baseline and the raw count is accumulated into a "bucket." When the bucket fills completely, the baseline increments and the bucket is emptied. The Baseline Update Threshold parameter sets the threshold that the bucket must reach for the baseline to increment.

Possible values are 0 to 255.

3.4.6 Negative Noise Threshold

The Negative Noise Threshold parameter acts as a negative difference count threshold. If the raw count is below the baseline minus the negative noise threshold for the number of samples specified by the Low Baseline Reset parameter, the baseline is set to the new raw count value.

Possible values are 0 to 255.

3.4.7 Low Baseline Reset

The Low Baseline Reset parameter works together with the Negative Noise Threshold parameter. It counts the number of abnormally low samples required to reset the baseline. It is used to correct the finger-on-at-startup condition.

Possible values are 0 to 255.

3.4.8 Sensors Autoreset

This parameter determines whether the baseline is updated at all times, or only when the difference counts are below the noise threshold.

When Sensors Autoreset is enabled, the baseline is updated constantly. This limits the maximum time duration of the sensor (typical values are 5 to 10 seconds), but prevents the sensors from permanently turning on when the raw count accidentally rises without anything touching the sensor. This sudden rise can be caused by a large power supply voltage fluctuation, a high-energy RF noise source, or a very quick temperature change.

When Sensors Autoreset is disabled, the baseline is updated only when the difference counts are below the noise Threshold parameter.

Possible values are Enabled and Disabled.

3.4.9 High-Level Parameter Recommendations

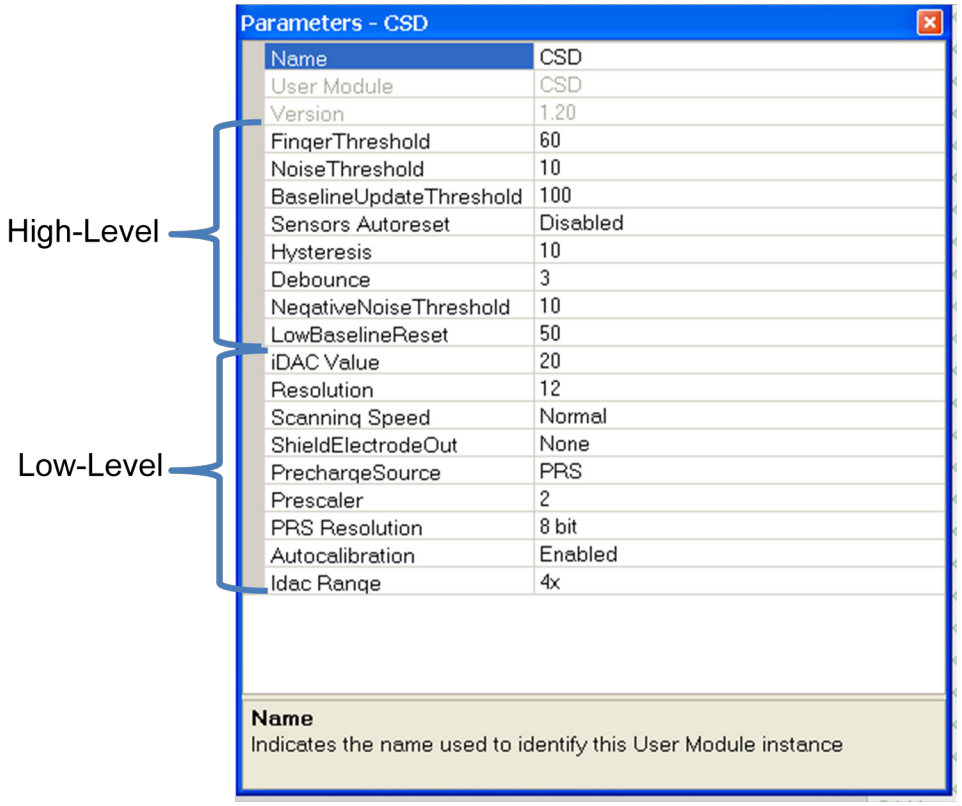
The following recommendations are only a starting place for selecting the optimal parameter settings

- **Finger Threshold**: Set to 75 percent of Raw Counts with sensor ON
- **Noise Threshold**: Set to 40 percent of Raw Counts with sensor OFF
- **Negative Noise Threshold**: Set equal to Noise Threshold
- **Baseline Update Threshold**: Set two times Noise Threshold
- **Hysteresis**: Set to 15 percent of Raw Counts with sensor ON
- **Low Baseline Reset**: Set to 10
- **Sensors Autoreset**: Based on design requirements
- **Debounce**: Based on design requirements

3.5 CSD User Module Low-Level Parameters

The CSD User Module has several low-level parameters in addition to the high-level parameters. These parameters are specific to the CSD sensing method and determine how raw count data is acquired from the sensor.

Figure 3-7. PSoC Designer - CSD Parameters WIndow



3.5.1 iDAC Value

The iDAC parameter sets the capacitance measurement range. A higher value corresponds to a wider range. Adjust the iDAC value such that raw counts are at about 50 to 70 percent of full range. This parameter can be changed in run time using the corresponding API function.

Possible values are 1 to 255.

3.5.2 Resolution

This parameter determines the scanning resolution in bits. The maximum raw count for scanning resolution of N bits is 2^{N-1}. Increasing the resolution improves sensitivity, but reduces scan time.

Possible values are 9 to 16 bits.

Table 3-1. Resolution and Scan Speed

	Scan Speed (µs)			
Resolution	**Ultra Fast**	**Fast**	**Normal**	**Slow**
9	57	78	125	205
10	78	125	205	380
11	125	205	380	720
12	205	380	720	1400
13	380	720	1400	2800
14	720	1400	2800	5600
15	1400	2800	5600	11000
16	2800	5600	11000	22000

3.5.3 Scanning Speed

This parameter sets sensor scanning speed. While faster scanning speed provides good response time, slower scanning speeds provide the following advantages:

- Improved SNR
- Better immunity to power supply and temperature changes
- Less demand for system interrupt latency; you can handle longer interrupts

Possible values are Ultra Fast, Fast, Normal, and Slow.

3.5.4 Shield Electrode Out

A shield electrode is used to reduce parasitic capacitance. This parameter selects where to route the output of the shield electrode.

Possible values are P0[7] or P1[2].

3.5.5 Precharge Source

This parameter selects the clock source for precharge switches.

Possible values are PRS and Prescaler. Use the PRS source in most cases to get better EMI immunity and lower emission.

3.5.6 Prescaler

This parameter sets the prescaler ratio and determines the precharge switch output frequency. This parameter also affects the PRS output frequency.

Possible values are 1, 2, 4, 8, 16, 32, 64, 128, and 256.

3.5.7 PRS Resolution

This parameter changes the PRS sequence length.

Possible values are 8-bit and 12-bit. Corresponding sequence lengths are 511 and 2047 input clock periods. Use an 8-bit setting if 12-bit does not provide good SNR.

3.5.8 Autocalibration

When Autocalibration is enabled, the Raw Count value is normalized as a percentage of the max count (2^{N-1}) where N is the resolution. Autocalibration overrides the device editor settings.

When Autocalibration is disabled, the Raw Count value depends on iDAC Range, iDAC value, resolution, sensor capacitance, IMO frequency, prescaler, precharge source, and V_{ref} parameters set in the device editor.

Autocalibration consumes ROM and RAM resources and increases start time. Autocalibration does not automatically select the iDAC Range value. If the Raw Count value after calibration is less than half of the resolution range, you should increase the iDAC Range or reduce the precharge frequency. Autocalibration works to improve marginally functional configurations.

3.5.9 iDAC Range

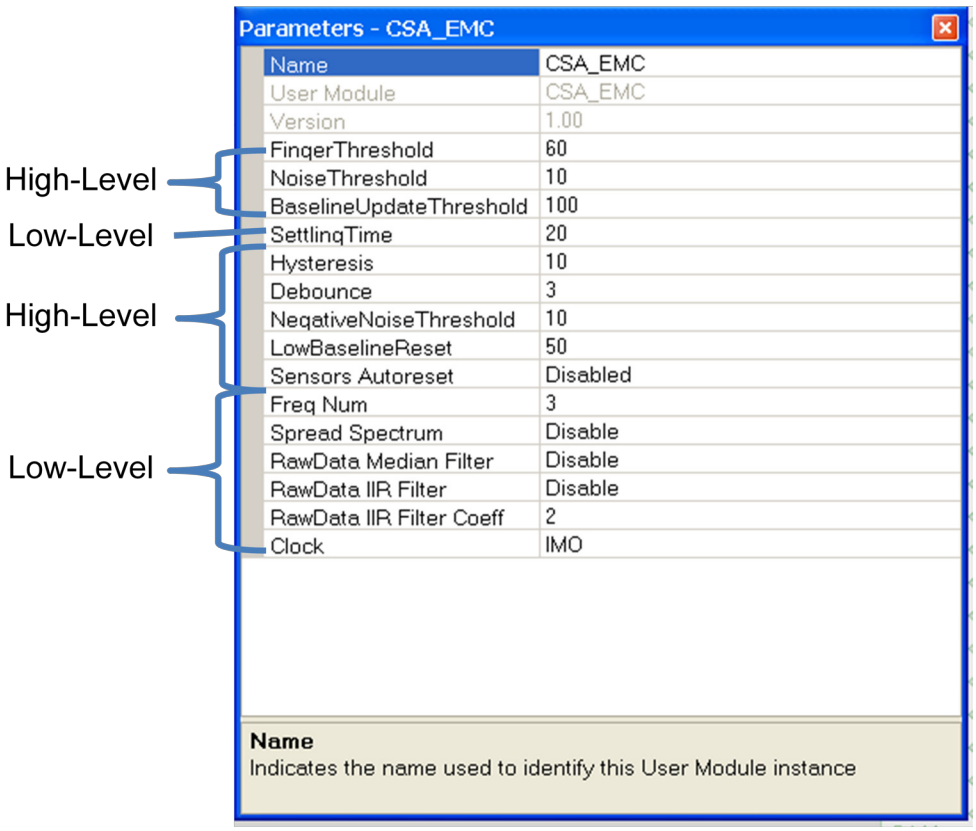
The iDAC Range parameter scales the iDAC current output. For example, selecting 2x will scale the iDAC output to twice the range

Possible values are 1x, 2x, 4x, and 8x.

3.6 CSA_EMC User Module Low-Level Parameters

The CSA_EMC User Module has several low-level parameters in addition to the high-level parameters. These parameters are specific to the CSA_EMC sensing method and determine how Raw Count data is acquired from the sensor.

Figure 3-8. PSoC Designer - CSA_EMC Parameter Window



3.6.1 Settling Time

The Settling Time parameter controls the software delay that allows the voltage on the C_{MOD} capacitor to stabilize. Each loop has nine CPU cycles per iteration. Select a settling Time based on Equation 5.

$$Settling\ Time\ \geq 10 \times R_{series} \times C_P \qquad \textbf{Equation 5}$$

Where:

R_{series} = 400-Ω + series resistor placed between port pin and sensor (typical value 560 Ω)

C_P = sensor base capacitance

Possible values are 2 to 255.

3.6.2 Freq Num

This parameter improves EMC performance by implementing a patented EMC improvement technology. Freq Num = 1 corresponds to the standard scanning algorithm and Freq Num = 3 turns on the advanced algorithm. Enabling the advanced scanning algorithm increases the scanning time and RAM usage by a factor of three.

Possible values are 1 (standard scanning algorithm) and 3 (advanced algorithm).

3.6.3 Spread Spectrum

This parameter improves EMC performance by implementing a firmware-based spread-spectrum technique that randomly changes the clock value during scanning. Spread spectrum is enabled when Freq Num is set to 1.

Possible values are 1 (enabled) and 3 (disabled).

3.6.4 Raw Data Median Filter

The median filter looks at the three most recent samples from a sensor and reports the median value. It is used to remove short noise spikes. This filter generates a delay of one sample. This filter is generally not recommended because of the delay and RAM usage. Enabling this filter consumes (Number of Sensors × 2 × Freq Num) bytes of RAM and 100 bytes of Flash. It is disabled by default.

Possible values are Enabled and Disabled.

3.6.5 RawData IIR Filter

This infinite impulse response (IIR) filter reduces noise in the conversion result (raw count). Filtering on the raw counts can be more effective than filtering the XY coordinate, but requires more RAM. Enabling this filter consumes an additional 100 bytes of Flash. It is disabled by default. The default IIR coefficient is 0.5.

Possible values are Enabled and Disabled.

3.6.6 RawData IIR Filter Coefficient

This is the coefficient for the Raw Count IIR filter.

Possible values are 2 (½ previous sample + ½ current sample) and 4 (¾ previous sample + ¼ current sample).

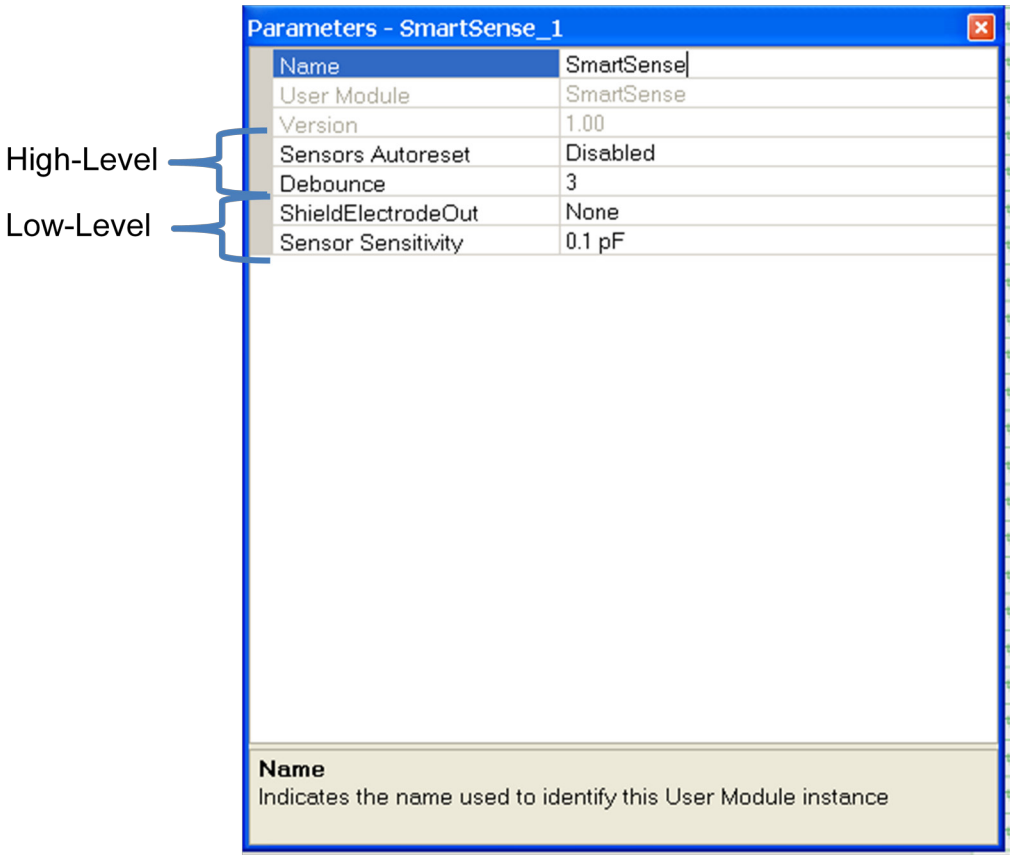
3.6.7 Clock

The Clock parameter can be used to increase the amount of effective resistance of the sensor. If the sensor area is large, the effective resistance may be too high for the autocalibration of the switched capacitor circuit. Large proximity sensors may encounter decreased sensitivity. In this case, the settling voltage is too far below the comparator threshold. Setting a larger divider of the internal main oscillator (IMO) increases the effective resistance, compensating for the high capacitance.

Possible values are IMO, IMO/2, IMO/4, and IMO/8.

3.7 SmartSense User Module Parameters

Figure 3-9. PSoC Designer SmartSense Parameters



3.7.1 Shield Electrode Out

A shield electrode is used to reduce parasitic capacitance. This parameter selects where to route the output of the shield electrode.

Possible values are P0[7] or P1[2].

3.7.2 Sensor Sensitivity

This parameter is used to increase and decrease the sensitivity of a sensor.

Possible values are 0.1 pF, 0.2 pF, 0.3 pF, and 0.4 pF

3.7.3 Multi-Chart for monitoring CapSense user module parameters

Tuning the CapSense system requires you to monitor the CapSense User Module global arrays. Multi-chart helps to monitor this parameter very easily. Refer to application note AN2397 for more details on the use of the multi-chart tool.

4. CapSense Performance Tuning with User Modules

Optimal user module parameter settings depend on board layout, button dimensions, overlay material, and application requirements. These factors are discussed in Design Considerations. Tuning is the process of identifying the optimal parameter settings for robust and reliable sensor operation.

4.1 General Considerations

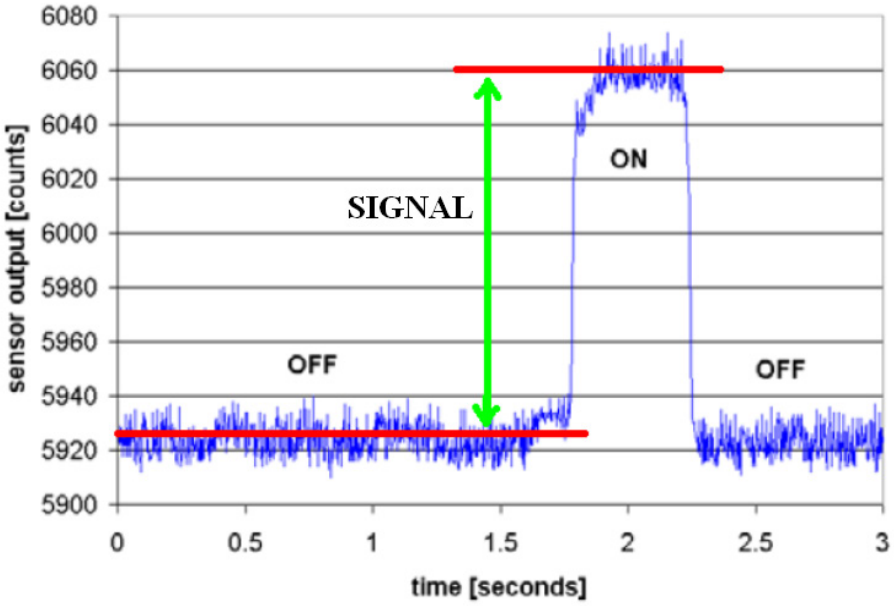
4.1.1 Signal, Noise, and SNR

A well-tuned CapSense system reliably discriminates between ON and OFF sensor states. To achieve this level of performance, the CapSense signal must be significantly larger than the CapSense noise. The measure that compares signal to noise is the signal-to-noise Ratio (SNR). Before discussing the meaning of SNR for CapSense, it is first necessary to define what signal and noise are in the context of touch sensing.

4.1.1.1 CapSense Signal

The CapSense signal is the change in the sensor response when a finger is placed on the sensor, as demonstrated in Figure 4-1. The output of the sensor is a digital counter with a value that tracks the sensor capacitance. In this example, the average level without a finger on the sensor is 5925 counts. When a finger is placed on the sensor, the average output increases to 6060 counts. The CapSense signal tracks the change in counts due to the finger, so Signal = 6060 – 5925 = 135 counts.

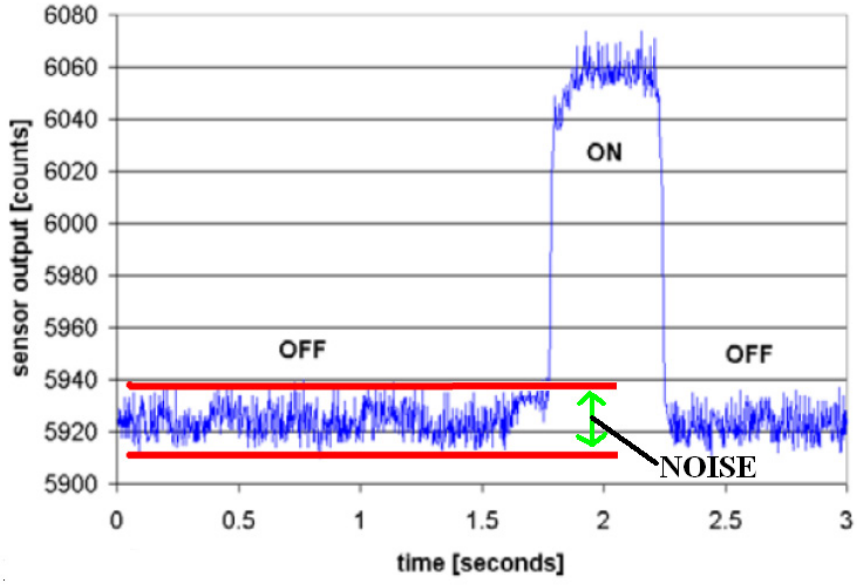
Figure 4-1. Example of CapSense Signal



4.1.1.2 CapSense Noise

CapSense noise is the peak-to-peak variation in sensor response when a finger is not present, as demonstrated in Figure 4-2. In this example, the output waveform without a finger is bounded by a minimum of 5912 counts and a maximum of 5938 counts. The noise is the difference between the min and the max values of this waveform, so Noise = 5938 – 5912 = 26 counts.

Figure 4-2. Example of CapSense Noise



4.1.1.3 CapSense SNR

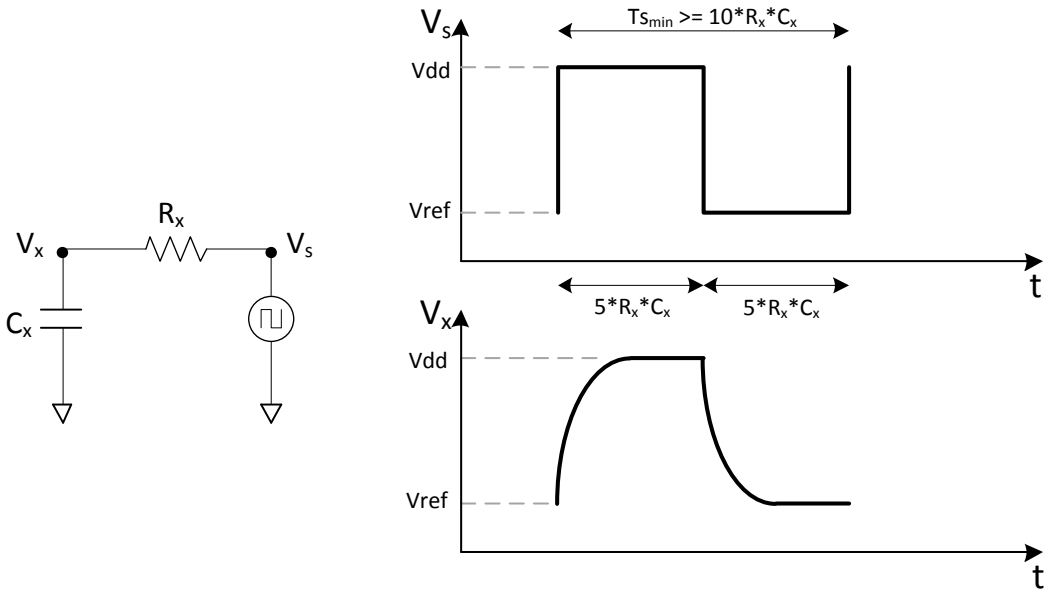
CapSense SNR is the simple ratio of signal and noise. Continuing with the example, if the signal is 135 counts and noise is 26 counts, then SNR is 135:26, which reduces to an SNR of 5.2:1. The minimum recommended SNR for CapSense is 5:1, which means the signal is five times larger than the noise. Filters are commonly implemented in firmware to reduce noise. Refer to Software Filtering for more information.

4.1.2 Charge/Discharge Rate

To achieve maximum sensitivity in the tuning process, the sensor capacitor must be fully charged and discharged during each cycle. The charge/discharge path switches between two states at a rate set by a user module parameter called Clock in the CSA_EMC User Module, and Precharge Clock in the CSD User Module.

The charge/discharge path includes series resistance that slows down the transfer of charge. The rate of change for this charge transfer is characterized by an RC time constant involving the sensor capacitor and series resistance, as shown in Figure 4-3.

Figure 4-3. Charge/Discharge Waveforms



Set the charge/discharge rate to a level that is compatible with this RC time constant. The rule of thumb is to allow a period of 5RC for each transition, with two transitions per period (one charge, one discharge).The equations for minimum time period and maximum frequency are:

$Ts_{min} = 10 \times R_X C_X$ **Equation 6**

$fs_{max} = \frac{1}{10 \times R_X C_X}$ **Equation 7**

For example, assume the series resistor includes a 560-Ω external resistor and up to 800 Ω of internal resistance, and the sensor capacitance is typical:

R_X = 1.4 kΩ

C_X= 24 pF

The value of the time constant and maximum front-end switching frequency in this example would be:

Ts_{min} = 0.34 µs

fs_{max} = 3 MHz

4.1.3 Importance of Baseline Update Threshold Verification

Temperature and humidity both cause the average number of counts to drift over time. The baseline is a reference count level for CapSense measurements that plays an important role in compensating for environmental effects. High-level decisions, such as Finger Present and Finger Absent states, are based on the reference level established by the baseline. Because each sensor has unique parasitic capacitance associated with it, each capacitive sensor has its own baseline.

Baseline tracks the change in counts at a rate set by the Baseline Update Threshold parameter. Make sure to match the update rate to the intended application. If the update rate is too fast, the baseline will compensate for any changes introduced by a finger, and the moving finger will not be detected. If the update rate is too slow, relatively slow environmental changes may be mistaken for fingers. During development, you should verify the Baseline Update Threshold settings.

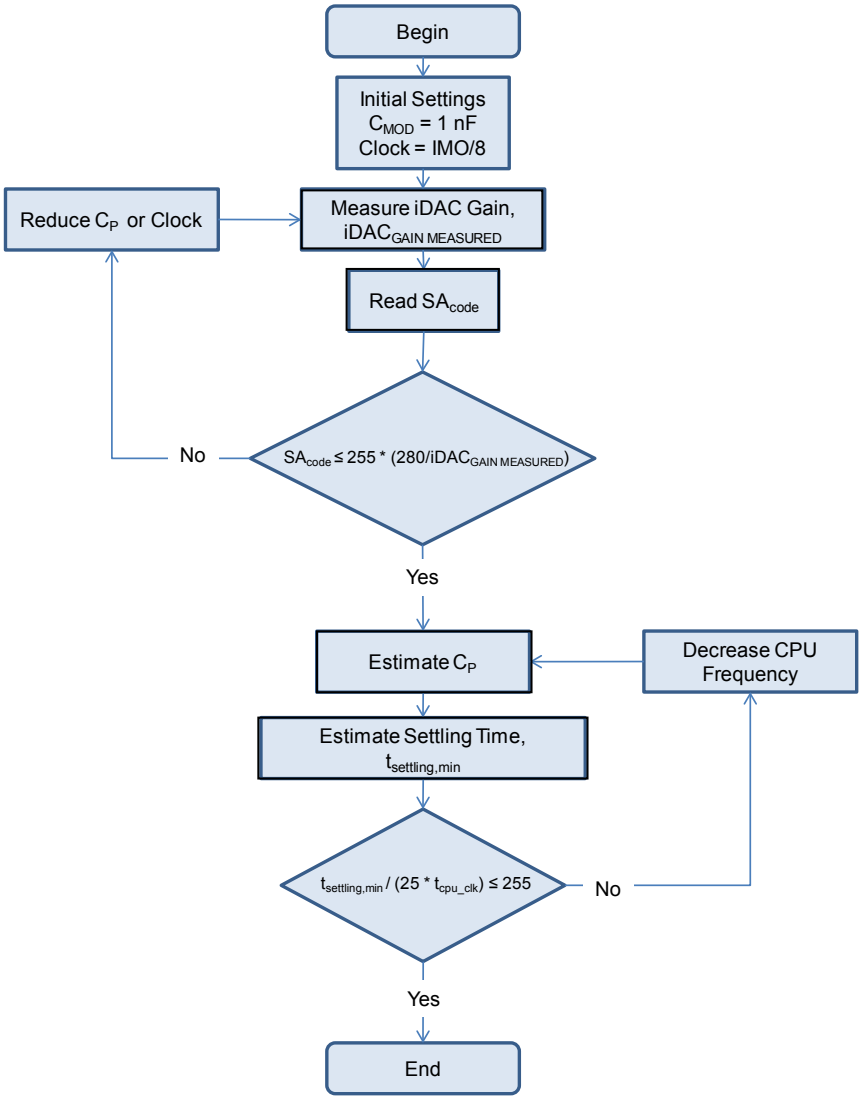
4.2 Tuning the CSA_EMC User Module

Manual selection of iDAC settings is not required for the CSA_EMC User Module; they are adjusted automatically. However, monitoring the iDAC settings can be useful for debugging or statistical process control.

4.2.1 Clock and Settling Time

The first step in tuning CSA_EMC User Module is to determine the settings for the clock and settling time. Figure 4-4 outlines the steps required to set these parameters.

Figure 4-4. Determining CSA_EMC Clock and Settling Times



4.2.1.1 Measure iDAC Gain

After following the steps to create a new PSoC Designer Project, use the following code snippet to route iDAC to port pin P1[0]:

```
//configure P1[0] to HI-Z
PRT1DM0 &= ~0x01;
PRT1DM1 |= 0x01;
//connect P1[0] to analog mux bus
MUX_CR1 |= 0x01;
// set iDAC to full scale
IDAC_D = 0xFF;
// turn iDAC on, 4x range
CS_CR2 = 0x90;
```

Place a current meter between pin P1[0] and ground, and measure current, $I_{MEASURED}$. Calculate the iDAC gain using Equation 8.

$$IDAC_{GAIN\ MEASURED} = \frac{I_{MEASURED}}{1020}$$ **Equation 8**

4.2.1.2 Read SA Code

iDAC code found in the successive approximation is termed as SA code. SA codes computed by CSA_EMC algorithm for each sensor can be read from array CSA_EMCbaDACCodeBaseline.

4.2.1.3 Estimate C_P

C_P can be estimated by using an LCR meter or by applying the following equations.

$$f_{SW} = \frac{IMO}{CSA\_EMC\ CLOCK}$$ **Equation 9**

$$C_P = \frac{4 \times SA_{CODE} \times IDAC_{GAIN\ MEASURED}}{V_{ref} \times f_{SW}}$$ **Equation 10**

Where:

V_{ref} = 1.2 V

4.2.1.4 Estimate Settling Time

The minimum Settling Time is estimated using Equation 11.

$$t_{settling,min} = \frac{5 \times C_{MOD} \times V_{ref}}{4 \times SA_{CODE} \times IDAC_{GAIN\ MEASURED}}$$ **Equation 11**

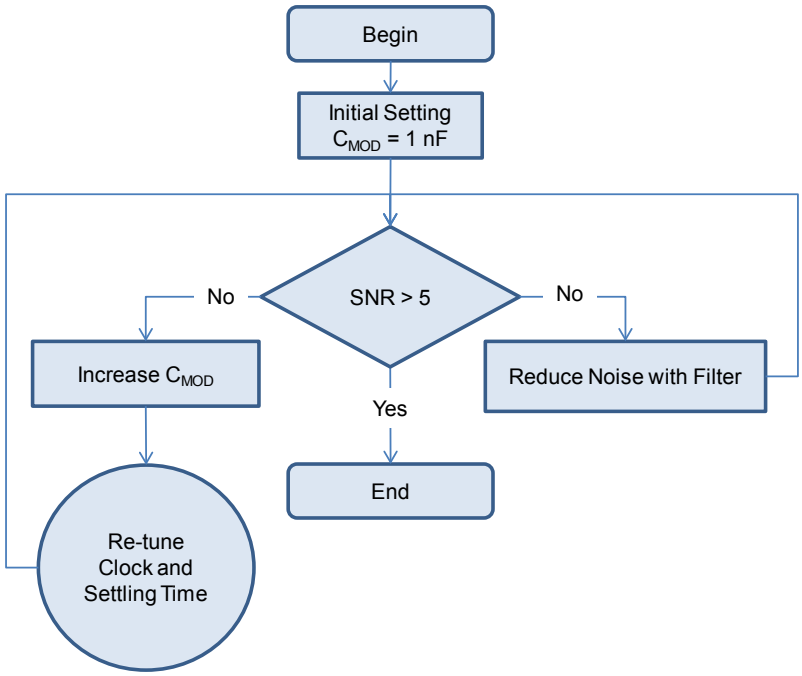
Where:

V_{ref} = 1.2 V

4.2.2 C_{MOD}

After the Clock and Settling Time are set, select the C_{MOD} value. Figure 4-5 outlines the steps for this part of the tuning process. If you need to adjust the C_{MOD} value, clock and settling time must be retuned, as described in Figure 4-4.

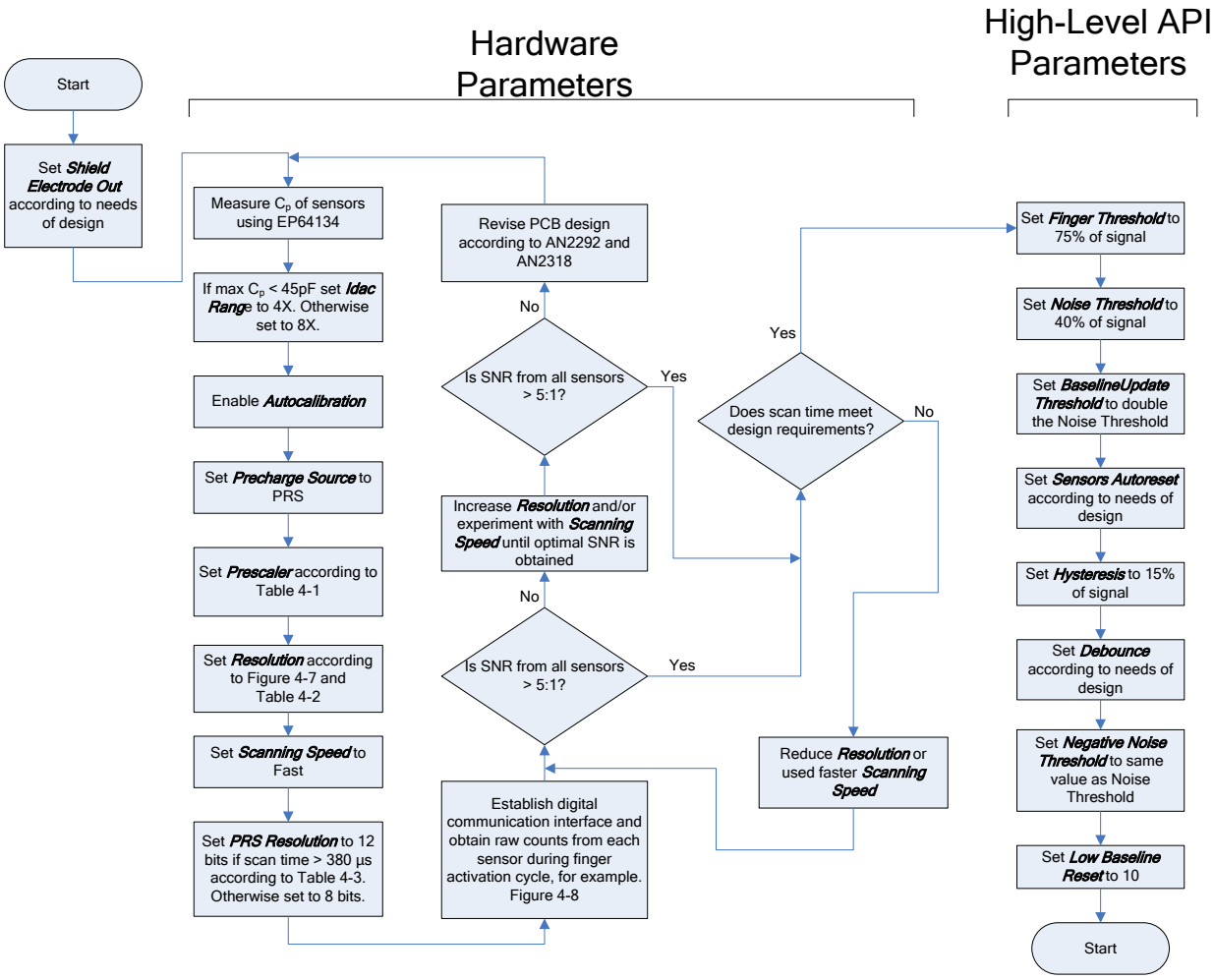
Figure 4-5. Determining CSA_EMC C_{MOD} Value



4.3 Tuning the CSD User Module

Figure 4-6 is a flowchart showing the tuning process for CSD UM parameters. CSD UM parameters can be separated into two broad categories, hardware parameters and high-level API parameters. The parameters in these categories affect the behavior of the capacitive sensing system in different ways and are therefore treated separately in this section. There is, however, a complementary relationship between the sensitivity of each sensor as determined by the hardware parameter settings and many of the high-level API parameter settings. Be mindful of this fact when any hardware parameter is changed to ensure that the corresponding high-level API parameters are adjusted accordingly. Tuning CSD User Module parameters should always begin with the hardware parameters.

Figure 4-6. Tuning the CSD User Module



Hardware parameters configure the hardware that the CSD method uses to convert the physical capacitance of each sensor into a digital code. This section describes these parameters and provides guidance on how each should be tuned based on system characteristics and other parameters.

By default, hardware parameters are global settings that apply to all CapSense sensors in a design. In designs where total parasitic capacitance of each sensor (C_P), sensor sensitivity, or both vary over a wide range, there may not be global hardware parameter settings that are suitable for all sensors. In such cases, the SetIdacValue(i), SetPrescaler(i), and SetScanMode(i) API functions can be used to configure the respective hardware parameters for each sensor where (i) is the sensor index prior to calling the ScanSensor(i) API function.

Table 4-1 and Table 4-3 provide tuning recommendations for several key hardware parameters based on sensor C_P. C_P values depend on characteristics of the PSoC, PCB layout, and proximity of other components in the assembled product. That being the case, C_P must be measured in its original position with the system in its final assembled state; that is, in the same enclosure and with the same overlay as the system will have in service. The best way to measure C_P is to use the code example titled Measuring Absolute Sensor Capacitance with a CY8C20xx6 CapSense Controller (EP64134). This project measures the absolute capacitance of each sensor in a system using the PSoC itself, thus taking into account all factors affecting C_P. See the documentation associated with the code example for instructions on its setup and use

ShieldElectrodeOut

Enable the ShieldEletrodeout for this design.

Idac Range

For projects where the maximum sensor C_P is less than 45 pF, use 4X; otherwise, use 8X.

Autocalibration

Autocalibration should always be set to Enabled in CY8C20xx6A CSD designs. The ability of the autocalibration algorithm to successfully set the iDAC relies on the prescaler being set properly and that C_{MOD} be of the recommended size.

iDAC Value

This parameter determines the current output of iDAC when autocalibration is disabled. When autocalibration is enabled, as recommended, this parameter is overridden and has no effect. When autocalibration is disabled, raising this parameter lowers the raw count baseline and vice versa.

Precharge Source

This parameter selects the sensor switching clock source. The available options are Prescaler, which uses the IMO through a divider, or PRS, which passes the divided IMO clock through a pseudo random generator, providing a spread-spectrum clock. PRS provides superior noise immunity and lower noise emissions and is therefore the recommend default setting for Precharge Source. In some instances, the prescaler precharge source can provide higher SNR (signal-to-noise ratio). However, when using copper circuitry, this SNR improvement is usually marginal and rarely justifies foregoing the benefits of PRS.

Prescaler

Prescaler is the divider applied to the IMO to develop the precharge clock. This is the most critical hardware UM parameter for properly tuning a CSD design. Prescaler depends on the selected precharge source, IMO, and the C_P of the sensors being scanned. Table 4-1 provides recommended prescaler settings based on these parameters.

Table 4-1. Prescaler Setting Based on Precharge Source, IMO, and C_P

C_P (pF)	Precharge Source = PRS			Precharge Source = Prescaler		
	Prescaler IMO = 24 MHz	Prescaler IMO = 12 MHz	Prescaler IMO = 6 MHz	Prescaler IMO = 24 MHz	Prescaler IMO = 12 MHz	Prescaler IMO = 6 MHz
<6	1	Note 1	Note 1	2	1	1
7–11	2	1	Note 1	4	2	1
12–15	2	1	Note 1	4	2	1
16–19	4	2	1	8	4	2
20–22	4	2	1	8	4	2
23–26	4	2	1	8	4	2
27–30	4	2	1	8	4	2
31–34	4	2	1	8	4	2
35–37	8	4	2	16	8	4
38–41	8	4	2	16	8	4
42–45	8	4	2	16	8	4
46–49	8	4	2	16	8	4
50–52	8	4	2	16	8	4
53–56	8	4	2	16	8	4
57–60	8	4	2	16	8	4

Note 1 This combination of Precharge Source, Prescaler, and C_P is not recommended.

Resolution

Available choices are 9 to 16 bits. Raising the resolution raises sensitivity, SNR, and noise immunity at the expense of scan time. The maximum raw count (full scale range) for scanning resolution n is 2n – 1. Table 4-2 provides recommended resolution settings based on C_P and the finger capacitance C_F. C_F is the change in capacitance of a sensor when a finger is placed on the sensor. C_F depends on overlay thickness, sensor size, and proximity of the sensor to other large conductors. Figure 4-7 provides C_F values as a function of overlay thickness and circular sensor diameter.

Figure 4-7. Finger Capacitance (C_F) Based on Overlay Thickness and Circular Sensor Diameter

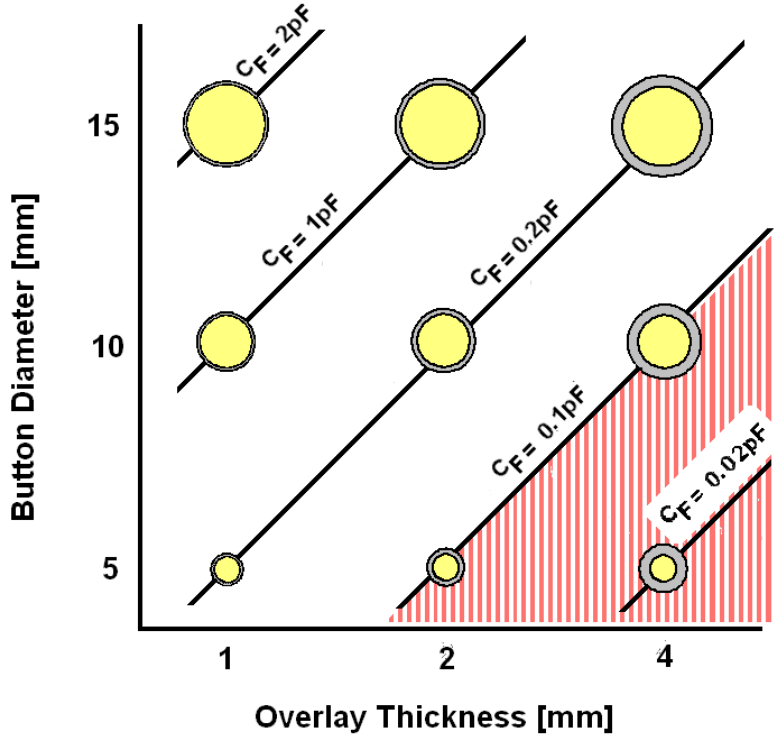


Table 4-2. Resolution Setting Based on Finger Capacitance and C_P

C_P (pF)	C_F = 0.1 pF	C_F = 0.2 pF	C_F = 0. 4pF	C_F = 0.8 pF
<6	12	11	10	9
7–12	13	12	11	10
13–24	14	13	12	11
25–48	15	14	13	12
>49	16	15	14	13

Scanning Speed

This parameter controls the integration time for each LSB of the scan result. The choices are Ultra Fast, Fast, Normal, and Slow. Fast is generally a good starting point. In some, but not all cases, slower scanning speed can yield higher SNR at the expense of longer scan time and more power consumption. Table 4-3 shows the actual scan time in microseconds for a single sensor based on resolution and scanning speed.

Table 4-3. Scan Time for a Single Sensor in µs Based on Resolution and Scanning Speed

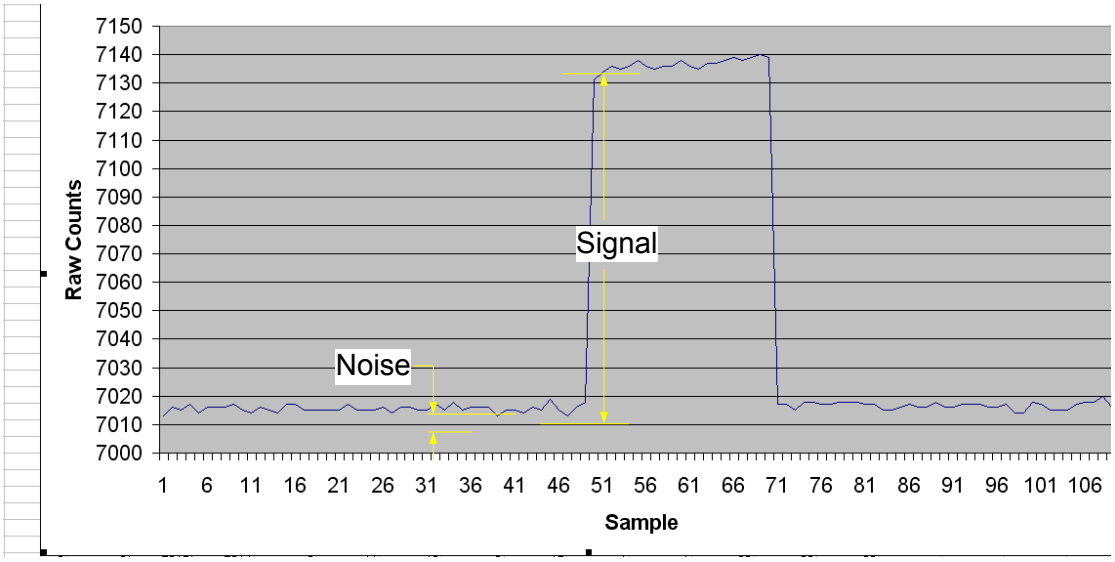
Resolution (bits)	Scanning Speed			
	Ultra Fast	**Fast**	**Normal**	**Slow**
9	57	78	125	205
10	78	125	205	380
11	125	205	380	720
12	205	380	720	1400
13	380	720	1400	2800
14	720	1400	2800	5600
15	1400	2800	5600	11000
16	2800	5600	11000	22000

4.3.1 High-Level API Parameters

High-level API parameters determine the behavior of high-level firmware algorithms that discriminate between sensor activations and noise, and compensate for signal drift caused by environmental conditions. In order to determine proper values for these parameters, you must establish a digital communication interface with the system to monitor raw counts, baseline, and difference counts during a finger activation event for each sensor. This data is stored in arrays named CSD_waSnsBaseline[], CSD_waSnsResult[], and CSD_waSnsDiff[], respectively. The high-level API parameter settings are based primarily on ambient noise and finger signal strength, as indicated by this data. Noise and signal strength depend on EMI environment, PCB layout, overlay thickness, and other physical characteristics of the system. Therefore, the data used as the basis for setting these parameters must be taken in its original position with the system in its final assembled state and in the same EMI environment as will exist in use.

Figure 4-8 shows the typical raw counts obtained from a sensor during a finger activation cycle; that is, the sensor is activated then deactivated. Labels are superimposed over the data that indicate how noise and signal are to be calculated based on the raw data. Where appropriate, the high-level parameter descriptions that follow include information about how to set each parameter based on these noise and signal values. According to AN2403, the ratio of signal to noise (SNR) must be at least 5:1 for robust CapSense system operation. If SNR is less than 5:1, the hardware parameters must be adjusted, the PCB layout changed according to the guidelines of AN2292 and AN2318 to raise SNR to at least 5:1, or both.

Figure 4-8. Typical Raw Counts from a Sensor During Finger Activation Cycle



4.3.2 Set High-Level Parameters

The following recommendations are a starting place for selecting the optimal parameter settings:

- **Finger Threshold**: Set to 75 percent of Raw Counts with sensor ON
- **Noise Threshold**: Set to 40 percent of Raw Counts with sensor OFF
- **Negative Noise Threshold**: Set equal to (Noise Threshold/2)
- **Baseline Update Threshold**: Set to two times Noise Threshold
- **Hysteresis**: Set to 15 percent of Raw Counts with sensor ON
- **Low Baseline Reset**: Set to 50
- **Sensors Autoreset**: Based on design requirements
- **Debounce**: Based on design requirements

4.4 Using the SmartSense User Module

SmartSense enables you to create a CapSense design that requires no tuning, as long as the sensor parasitic capacitance is in the range from 5 pF to 45 pF with a minimum 0.1-pF finger touch. You can create a SmartSense design by using the SmartSense User Module in PSoC Designer 5.1. This section also shows you how to migrate an existing CSD CapSense design to SmartSense.

4.4.1 Guidelines for SmartSense

Follow these guidelines when using the SmartSense User Module in an application:

- SmartSense requires capacitive user interface design to follow the layout and system design best practices documented in the previous sections of this design guide.
- All of the CSD User Module parameters (such as iDAC value, prescaler period, clock divider, scan speed, resolution) are determined at run time by the SmartSense User Module. You should not use APIs that modify these CSD parameters in firmware, unless you know exactly what effect it has in your design.
- To migrate an existing design from CSD to SmartSense,
  - ☐ Ensure that all APIs that set or modify the CSD parameters are first removed from the program.
  - ☐ Ensure that the parasitic capacitance of all CapSense sensors in the design is between 5 pF and 45p F over environmental and PCB production process variations.
  - ☐ Make sure recommended C_{MOD} capacitor (X7R, 2.2-nF, voltage rating more than 5 V) is connected to the C_{MOD} port pin selected in the user module wizard.

4.4.2 Understanding the Difference

The differences between the SmartSense User Module and the standard CSD User Module are:

- The SmartSense User Module supports APIs that a standard CSD User Module supports. Thus, no change is required in placing, configuring, starting, or calling other APIs except the User Module instance name.
- There is no need to set any User Module parameters for tuning, as all the parameters related to tuning are automatically set at run time by the SmartSense User Module.
- The C_{MOD} capacitor value is restricted to 2.2 nF. Use of an X7R capacitor with a voltage rating higher than 5 V is recommended in all CapSense applications.
- The SmartSense algorithm maintains the signal SNR of each sensor between 5:1 and 11:1 to ensure robust CapSense operation while maximizing performance.
- The scanning time of the SmartSense User Module is restricted by the algorithm to be between 410 µs and 2.8 ms per sensor in 24-MHz operating mode, based on the parasitic capacitance of the sensor.

4.4.3 SmartSense User Module Parameters

Only four parameters must be set for this user module. These are:

- Sensors Autoreset
- Debounce
- Modulator Capacitor Pin
- Shield Electrode Out

4.4.3.1 Sensors Autoreset

This parameter determines whether the baseline is updated at all times or only when the signal difference is below the noise threshold. When set to Enabled the baseline is updated constantly. This setting limits the maximum time that a sensor may remain on (typically it is 5 to 10 seconds), but it prevents the sensors from permanently turning on when the raw count suddenly rises without anything touching the sensor due to any failure condition of the system.

4.4.3.2 Debounce

The Debounce parameter adds a debounce counter to the sensor's active transition. For the sensor to be declared as active from inactive state, a finger touch signal should be present on the sensor for debounce number of consecutive scans. This parameter affects all the sensors similarly.

4.4.3.3 Modulator Capacitor Pin

This parameter selects the pin to which the 2.2 nF/X7R/voltage rating more than 5 V C_{MOD} capacitor is connected. The available pins are P0[1] and P0[3].

Note An external 2.2-nF capacitor is mandatory for the SmartSense to work correctly.

4.4.4 Scan Time of a CapSense Sensor

To maintain the consistent finger response sensitivity over a wide range of parasitic capacitance, the SmartSense User Module automatically determines the hardware parameters of the user module. As a result of this, sensor scan time does not remain constant. For a design in mass production, it could vary based on the parasitic capacitance variation of the PCB.

The total scan time of a sensor is decided by four factors. They are parasitic capacitance of sensor, IMO frequency, CPU operating frequency, and sensitivity level of the SmartSense User Module.

Scan time of a sensor can be found using Equation 12 and the following tables.

$$Scan\ time = Sampling\ time\ (ST) + Processing\ time\ (PT) \quad \textbf{Equation 12}$$

The following tables show the sampling time value with various IMO and sensitivity levels.

Table 4-4. Sampling Time for a Sensor with IMO = 24 MHz

Sensitivity = 0.2 pF		Sensitivity = 0.3 pF		Sensitivity = 0.4 pF	
C_P (pF)	ST (µs)	C_P (pF)	ST (µs)	C_P (pF)	ST (µs)
8 to 10	340	8 to 17	340	8 to 10	170
10 to 23	680	17 to 35	680	10 to 23	340
23 to 41	1360	35 to 41	1360	23 to 41	680
41 to 45	2730	41 to 45	2730	41 to 45	1360

Table 4-5. Sampling Time for a Sensor with IMO = 12 MHz

Sensitivity = 0.2 pF		Sensitivity = 0.3 pF		Sensitivity = 0.4 pF	
C_P (pF)	ST (µs)	C_P (pF)	ST(µs)	C_P (pF)	ST (µs)
8 to 10	680	8 to 17	680	8 to 10	340
10 to 23	1360	17 to 35	1360	10 to 23	680
23 to 41	2730	35 to 41	2730	23 to 41	1360
41 to 45	5460	41 to 45	5460	41 to 45	2730

Table 4-6. Sampling Time for a Sensor with IMO = 6 MHz

Sensitivity = 0.2 pF		Sensitivity = 0.3 pF		Sensitivity = 0.4 pF	
C_P (pF)	ST (µs)	C_P (pF)	ST(µs)	C_P (pF)	ST (µs)
8 to 11	680	8 to 10	680	8 to 11	680
11 to 23	1360	10 to 17	1360	11 to 23	1360
23 to 42	2730	17 to 35	2730	23 to 41	2730
42 to 45	5460	35 to 41	5460	41 to 45	5460
		41 to 45	10920		

Table 4-7 shows the value for processing time with various CPU frequencies.

Table 4-7. Processing Time for a Sensor

CPU CLK	Processing Time (PT) in µs
24	71
12	142
6	284
3	568

For example, if a CapSense system is designed with 24-MHz IMO frequency, 6-MHz CPU clock (IMO/4), and SmartSense sensitivity level of 0.3 pF, the scan time of the sensor that has parasitic capacitance ~15 pF can be determined from the previous tables using Equation 12.

Sampling time for the above-mentioned configuration (24 MHz of IMO, 0.3 pF of sensitivity) is chosen from Table 4-4; it is 680 µs. Processing time for the above-mentioned configuration (CPU clock of 6 MHz) Is chosen from Table 4-7; it is 284 µs.

Thus, the total scan time in this configuration is 680 + 284 = 964 µs. Scan time for more than one sensor is the sum of the scan time of each sensor

4.4.5 SmartSense Response Time

Consider the following application with standard CSD along with typical CapSense scanning firmware.

Three CapSense sensors with parasitic capacitance of sensor between 5 pF and 10 pF

IMO of 12 MHz and CPU clock of 12 MHz

Sensor sensitivity level of 0.4 pF

Debounce = 3

According to the above tables, scanning of each sensor requires 482 µs and three sensors have a scan time of 1.45 ms. The following firmware example requires 1 ms for additional firmware execution; thus, the loop execution time would be 2.45 ms.

```
while (1)
{
```

```
    SmartSense_ScanAllSensors();
    SmartSense _UpdateAllBaselines();

    if(SmartSense _bIsAnySensorActive() )
    {
        //1mS firmware routines
    }
}
```

This means that, upon the activation of a CapSense sensor, firmware produces the sensor ON status within 7.35 ms (the sensor should be active for Debounce number of consecutive scans). This is often referred to as the response time of CapSense system.

If the scan time varies with respect to the parasitic capacitance to maintain consistent , what is the impact on response time if the parasitic capacitance of the sensor changes due the process variation? Response time may be increased (slow response) in this case. This can have a negative impact on sensor performance. Guidelines to build a robust firmware design are provided below.

4.4.6 Firmware Design Guidelines

The response time of the CapSense sensors may change due to the increased parasitic capacitance of the sensor. IT is also important to watch the loop execution time (see the following example code), which may also increase. When the parasitic capacitance of all sensors was less than 10 pF, the firmware routine was executed at a rate of 2.45 ms. This rate will be modified if the sensor scan time is increased because of the increase in the parasitic capacitance of the sensor based on the process variation.

The following is example code for toggling a port pin based on the main loop execution time.

```
   while (1)
   {
       SmartSense_ScanAllSensors();
       SmartSense_UpdateAllBaselines();

       if(SmartSense_bIsAnySensorActive() )
       {
           //1 ms firmware routines
       }

       PRT0DR_Shadow ^= 0x01;
       PRT0DR = PRT0DR_Shadow;
   }
```

The period of the signal on Port_0[1] pin is 4.9 ms (the period is twice the loop time as the port pin is toggled). If the parasitic capacitance of one sensor is increased to approximately 15 pF, the scan time will change to 1.78 ms; thus, the period of signal on the Port_0[1] will be 5.6 ms.

If the parasitic capacitance of the sensor is close to the boundary of the SmartSense capacitance banks (for example, 9 pF, which is very close to the 10-pF boundary), SmartSense may choose a neighboring scan time in an application due to process variation. Because of this, different production parts of the same design can have two different main loop execution times and response times.

Based on the above discussions, firmware should not rely on the scan time of the sensor for implementing other features (for example, software PWM, software delay, and so on). Programs implementing watch dog timer (WDT) should consider this fact while setting the WDT expiration time

A simple firmware implementation example to get a consistent main loop execution time using Timer16 User Module follows.

```
// Main program
BYTE bTimerTicks = 0;

#pragma interrupt_handler myTimer_ISR_Handler;
void myTimer_ISR_Handler( void );

void main()
{
   M8C_EnableGInt;
```

```
    SmartSense_Start();
    SmartSense_ScanAllSensors();
    SmartSense_SetDefaultFingerThresholds() ;

    Timer16_EnableInt();
    Timer16_SetPeriod (TIMEOUT_10MS) ;
    Timer16_Start();

    while( 1 )
    {
        /* Scan all 3 sensors and update
         Baseline */
        SmartSense_ScanAllSensors();
        SmartSense_UpdateAllBaselines();

        /* Wait till timer expires or
         sleep here */

        while (bTimerTicks != 1) ;
        bTimerTicks = 0 ;

        if(CSDAUTO_bIsAnySensorActive() )
        {
            //1 ms firmware routines
        }

        // Toggle Port_0[1]
        PRT0DR_Shadow ^= 0x01 ;
        PRT0DR = PRT0DR_Shadow ;
    }
}

// Timer16 ISR program
void myTimer_ISR_Handler(void)
{
bTimerTicks++;
}
```

In the previous example, the program waits for the Timer to expire even if the sensor scanning is complete. The period of the Timer should be chosen based on the worst case main loop execution time. This is the sum of the worst case scan times of the individual CapSense sensors. If the parasitic capacitance of the sensor is close to the boundary of the SmartSense capacitance bank, chose higher scan time (using Table 4-5 on page 38) for the calculation.

The SmartSense User Module enables you to easily implement the capacitive touch sensing user interface into a system. It removes the difficulties of the tuning process and also helps to increase the yield in production against manufacturing process variations of the PCB, and other variations. Therefore, the preferred option is to migrate the existing CSD-based CapSense designs to SmartSense and to use SmartSense for new designs.

The main loop execution time and scan time of SmartSense vary based on the process variations. Though it does not affect the performance of CapSense in any way, the firmware developer should consider this when implementing CapSense PLUS applications with SmartSense Auto-Tuning technology.

5. Design Considerations

When designing capacitive touch sense technology into your application, it is crucial to keep in mind that the CapSense device exists within a larger framework. Careful attention to every level of detail from PCB layout to user interface to end-use operating environment will lead to robust and reliable system performance. For more in-depth information, refer Getting Started with CapSense.

5.1 Overlay Selection

In CapSense Equivalent Model, Equation 1 was presented for finger capacitance

$$C_F = \frac{\varepsilon_0 \varepsilon_r A}{D}$$

Where:

ε_0 = Free space permittivity

ε_r = Dielectric constant of overlay

A = Area of finger and sensor pad overlap

D = Overlay thickness

To increase the CapSense signal strength, choose an overlay material with a higher dielectric constant, decrease the overlay thickness, and increase the button diameter.

Table 5-1. Overlay Material Dielectric Strength

Material	Breakdown Voltage (V/mm)	Min. Overlay Thickness at 12 kV (mm)
Air	1200–2800	10
Wood – dry	3900	3
Glass – common	7900	1.5
Glass – Borosilicate (Pyrex®)	13,000	0.9
PMMA Plastic (Plexiglas®)	13,000	0.9
ABS	16,000	0.8
Polycarbonate (Lexan®)	16,000	0.8
Formica	18,000	0.7
FR-4	28,000	0.4
PET Film – (Mylar®)	280,000	0.04
Polymide film – (Kapton®)	290,000	0.04

Conductive material cannot be used as an overlay because it interferes with the electric field pattern. For this reason, do not use paints containing metal particles in the overlay.

An adhesive is typically used to bond the overlay to the CapSense PCB. A transparent acrylic adhesive film from 3M™ called 200MP is qualified for use in CapSense applications. This special adhesive is dispensed from paper-backed tape rolls (3M™ product numbers 467MP and 468MP).

5.2 ESD Protection

Robust ESD tolerance is a natural by-product of thoughtful system design. By considering how contact discharge will occur in your end product, particularly in your user interface, it is possible to withstand an 18-kV discharge event without incurring any damage to the CapSense controller.

CapSense controller pins can withstand a direct 2-kV event. In most cases, the overlay material provides sufficient ESD protection for the controller pins. Table 5-1 lists the thickness of various overlay materials required to protect the CapSense sensors from a 12-kV discharge, as specified in IEC 61000-4-2. If the overlay material does not provide sufficient protection, ESD countermeasures should be applied in the following order: Prevent, Redirect, Clamp.

5.2.1 Prevent

Ensure all paths on the touch surface have a breakdown voltage greater than potential high-voltage contacts. Also, design your system to maintain an appropriate distance between the CapSense controller and possible sources of ESD. If it is not possible to maintain adequate distance, place a protective layer of a high breakdown voltage material between the ESD source and CapSense controller. One layer of 5-mil-thick Kapton® tape will withstand 18 kV.

5.2.2 Redirect

If your product is densely packed, it may not be possible to prevent the discharge event. In this case, you can protect the CapSense controller by controlling where the discharge occurs. A standard practice is to place a guard ring on the perimeter of the circuit board that is connected to chassis ground. As recommended in PCB Layout Guidelines, providing a hatched ground plane around the button or slider sensor can redirect the ESD event away from the sensor and CapSense controller.

5.2.3 Clamp

Because CapSense sensors are purposely placed in close proximity to the touch surface, it may not be practical to redirect the discharge path. In this case, including series resistors or special purpose ESD protection devices may be appropriate.

The recommended series resistance value is 560 Ω.

A more effective method is to provide special-purpose ESD protection devices on the vulnerable traces. ESD protection devices for CapSense need to be low capacitance. Table 5-2 lists devices recommended for use with CapSense controllers.

Table 5-2. Low-Capacitance ESD Protection Devices Recommended for CapSense

ESD Protection device		Input Capacitance	Leakage Current	Contact Discharge maximum limit	Air Discharge maximum limit
Manufacturer	Part Number				
Littlefuse	SP723	5 pF	2 nA	8 kV	15 kV
Vishay	VBUS05L1-DD1	0.3 pF	0.1 µA <	±15 kV	±16 kV
NXP	NUP1301	0.75 pF	30 nA	8 kV	15 kV

5.3 Electromagnetic Compatibility (EMC) Considerations

5.3.1 Radiated Interference

Radiated electrical energy can influence system measurements and potentially influence the operation of the processor core. The interference enters the PSoC® chip at the PCB level, through CapSense sensor traces and any other digital or analog inputs. Layout guidelines for minimizing the effects of RF interference include:

- **Ground Plane**: Provides a ground plane on the PCB.
- **Series Resistor**: Series resistors should be placed within 10 mm of the CapSense controller pins.
  - ☐ The recommended series resistance for CapSense input lines is 560 Ω.
  - ☐ The recommended series resistance for communication lines such as I^2C, and SPI is 330 Ω.
- **Trace Length**: Minimizes trace length whenever possible.

- **Current Loop Area**: Minimizes the return path for current. Hatched ground instead of solid fill should be provided within 1 cm of the sensors and traces to reduce the impact of parasitic capacitance.
- **RF Source Location**: Partition systems with noise sources such as LCD inverters and switched-mode power supplies (SMPS) to keep them separated from CapSense inputs. Shielding the power supply is another common technique for preventing interference.

5.3.2 Radiated Emissions

Selecting a low frequency for the switched capacitor clock will help to reduce radiated emissions from the CapSense sensor. This clock is controlled in firmware using the Prescaler option. Increasing the Prescaler value decreases the frequency of the switching clock

5.3.3 Conducted Immunity and Emissions

Noise entering a system through interconnections with other systems is referred to as conducted noise. These interconnections include power and communication lines. Because CapSense controllers are low-power devices, conducted emissions must be avoided. The following guidelines will help reduce conducted emission and immunity:

- Use decoupling capacitors as recommended by the datasheet.
- Add a bidirectional filter on the input to the system power supply. This is effective for both conducted emissions and immunity. A pi-filter can prevent power supply noise from effecting sensitive parts, while also preventing the switching noise of the part from coupling back onto the power planes.
- If the CapSense controller PCB is connected to the power supply by a cable, minimize the cable length and consider using a shielded cable.
- Place a ferrite bead around power supply or communication lines to filter out high-frequency noise.

5.4 Software Filtering

Software filters are one of the techniques for dealing with high levels of system noise. Table 5-3 lists the types of filters that have been found useful for CapSense.

Table 5-3. Table of CapSense Filters

Type	Description	Application
Average	Finite impulse response filter (no feedback) with equally weighted coefficients	Periodic noise from power supplies
IIR	Infinite impulse response filter (feedback) with a step response similar to an RC filter	High frequency white noise (1/f noise)
Median	Nonlinear filter that computes median input value from a buffer of size N	Noise spikes from motors and switching power supplies
Jitter	Nonlinear filter that limits current input based on previous input	Noise from thick overlay (SNR < 5:1), especially useful for slider centroid data
Event-Based	Nonlinear filter that causes a predefined response to a pattern observed in the sensor data	Commonly used during non-touch events to block CapSense data transmission.
Rule-Based	Nonlinear filter that causes a predefined response to a pattern observed in the sensor data	Commonly used during normal operation of the touch surface to respond to special scenarios such as accidental multibutton selection

Table 5-4 details the RAM and Flash requirements for different software filters. The amount of flash required for each filter type depends on the performance of the compiler. The requirements listed here are for both the ImageCraft compiler and the ImageCraft Pro compiler

Table 5-4. RAM and Flash Requirements

Filter Type	Filter Order	RAM (Bytes per sensor)	Flash (Bytes) ImageCraft Compiler	Flash (Bytes) ImageCraft Pro Compiler
Average	2–8	6	675	665
IIR	1	2	429	412
	2	6	767	622
Median	3	6	516	450
	5	10	516	450
Jitter filter on Raw Counts	N/A	2	277	250
Jitter filter on slider centroid	N/A	2	131	109

5.5 Power Consumption

5.5.1 System Design Recommendations

For many designs, minimizing power consumption is an important goal. There are several ways to reduce the power consumption of your CapSense capacitive touch-sensing system.

- Set GPIO drive mode for low power.
- Turn off the high-power blocks.
- Optimize CPU speed for low power.
- Operate at a lower V_{DD}.

In addition to these suggestions, applying the sleep-scan method can be very effective.

5.5.2 Sleep-Scan Method

In typical applications, the CapSense controller does not need to always be in the active state. The device can be put into the sleep state to stop the CPU and the major blocks of the device. Current consumed by the device in sleep state is much lower than the active current.

The average current consumed by the device over a long time period can be calculated by using the following equation.

$$I_{AVE} = \frac{(I_{Act} \times t_{Act}) + (I_{Slp} \times t_{Slp})}{T}$$ **Equation 13**

The average power consumed by the device can be calculated as follows:

$$P_{AVE} = V_{DD} \times I_{AVE}$$ **Equation 14**

5.5.3 Response Time versus Power Consumption

As illustrated in Equation 13, the average power consumption can be reduced by decreasing I_{AVE} or V_{DD}. I_{AVE} may be decreased by increasing sleep time. Increasing sleep time to a very high value will lead to poor CapSense button response time. As a result, the sleep time must be based on system requirements.

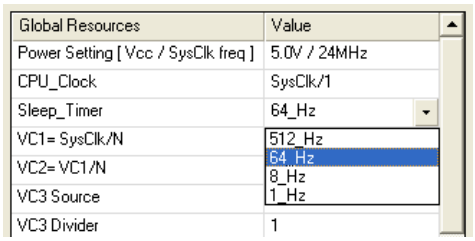
In any application, if both power consumption and response time are important parameters to be considered, an optimized method can be used that incorporates both continuous-scan and sleep-scan modes. In this method, the device spends most of its time in sleep-scan mode where it scans the sensors and goes to sleep periodically, as explained in the previous section, thereby consuming less power. When a user touches a sensor to operate the system, the device jumps to continuous-scan mode where the sensors are scanned continuously without invoking sleep, thereby giving very good response time. The device remains in continuous-scan mode for a specified timeout period. If the user does not operate any sensor within this timeout period, the device jumps back to the sleep-scan mode.

5.5.4 Measuring Average Power Consumption

The following instructions describe how to determine average power consumption when using the sleep-scan method:

1. Build a project that scans all of the sensors without going to sleep (continuous-scan mode). Include a pin-toggle feature in the code before scanning the sensors. Toggling the state of the output pin serves as a time marker that can be tracked with an oscilloscope.
2. Download the project to the CapSense device and measure the current consumption. Assign the measured current to I_{Act}.
3. Get the sleep current information from the datasheet and assign it to I_{Slp}.
4. Monitor the toggling output pin in the oscilloscope and measure the time period between two toggles. This gives the active time. Assign this value to t_{Act}.
5. Apply sleep-scan to the project. The time period of the sleep-scan cycle, T, is set by selecting the sleep timer frequency in the global resources window as shown in Figure 5-1.
6. Subtract active time from the sleep-scan cycle time period to get the sleep time. $t_{Slp} = T - t_{Act}$.
7. Calculate the average current using Equation 13.
8. Calculate average power consumption using Equation 14.

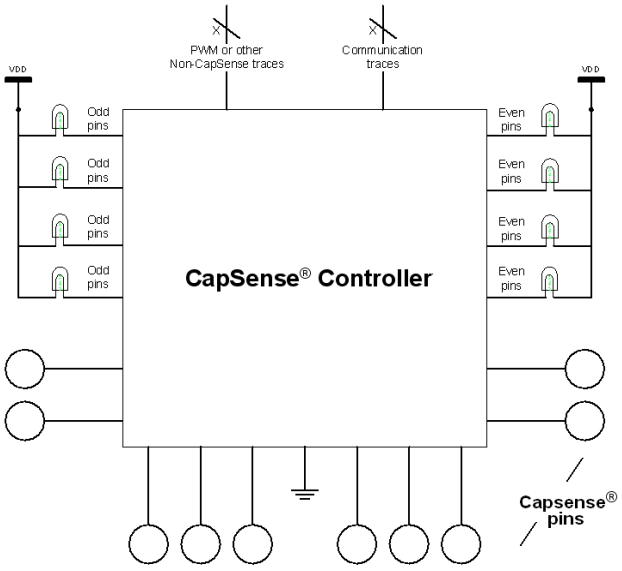
Figure 5-1. Global Resources Window



5.6 Pin Assignments

An effective method to reduce interaction between CapSense sensor traces and communication and non-CapSense traces is to isolate each by port assignment. Figure 5-2 shows a basic version of this isolation for a 32-pin QFN package. Because each function is isolated, the CapSense controller is oriented such that there is no crossing of communication, LED, and sensing traces.

Figure 5-2. Recommended: Port Isolation for Communication, CapSense and LEDs



The architecture of the CapSense controller imposes a restriction on current budget for even and odd port pin numbers. An odd pin can be any port pin having an odd number as pin number. For a CapSense controller, if the current budget of odd port pin is 100 mA, total current drawn though all odd port pins should not exceed 100 mA. In addition to the total current budget limitation, there is also a maximum current limitation for each port pin that is defined in the CapSense controller datasheet.

All CapSense controllers provide high-current sink and source capable port pins. When using high-current sink or source from port pins, it is recommended to use the ports that are closest to device ground pin to minimize the noise.

5.7 PCB Layout Guidelines

Detailed PCB layout guidelines are available in Getting Started with CapSense.

6. Design Considerations

Power consumption is an important aspect of microcontroller designs. Among the several techniques to reduce the average current used by PSoC, sleep mode is the most popular. PSoC uses sleep mode when it is not required to perform any function, similar to a cell phone backlight dimming after an idle period. This is done to reduce the average current consumed by the device, a necessity of all battery applications. The PSoC enters sleep mode by writing a “1” to the SLEEP bit within the CPU_SCR0 register (Bit 3). This is accomplished by calling the M8C_Sleep macro. While in sleep mode, the central CPU is stopped, the internal main oscillator (IMO) is disabled, the Bandgap Voltage reference is powered down, and the Flash Memory Model is disabled. The only circuits left in operation are supply voltage monitor and 32-kHz internal oscillator. Power saving techniques other than sleep mode are:

- Disable PSoC analog block references
- Disable CT and SC blocks
- Disable PSoC analog output buffers
- Set drive Modes to analog HI-Z

Sleep mode has negative effects for a design. If not used carefully, it can cause unpredictable operation. The PSoC must be correctly awakened from sleep when necessary, and the user must be aware that the device is sleeping to allow extra processing.

6.1 Additional Power Saving Techniques

All of the power saving techniques, with the exception of sleep mode, are application based and some of these produce undesirable results. Each technique is discussed in detail below.

```
ABF_CR0 &= 0xc3; // Buffer Off
```

6.1.1 Set Drive Modes to Analog HI-Z

The state of the PSoC drive modes can affect power consumption. You can change the drive modes only on pins that do not cause adverse affects to the system. The change must occur in a sequence that does not produce line glitches. This sequence depends on the current drive mode of the pin and the state of port data register. With the PSoC drive mode structure, the pin must temporarily be in either Resistive Pull Up or Resistive Pull Down drive mode when switching between HI-Z or Strong drive modes. The temporary drive mode is the opposite of the previous value on the pin. So, if the pin was driven high, then the temporary drive mode must be Resistive Pull Down. This ensures that the drive mode of the pin is not resistive, which eliminates any possible glitch.

The drive modes are set manually in software, before going to sleep. There are three registers, PRTxDM0, PRTxDM1, and PRTxDM2, which control the drive modes. One bit per register is assigned to a pin. So, to change the drive mode of a single pin, three register writes are needed. However, this is convenient because an entire port is changed by the same three register writes. The correct pit pattern for Analog HI-Z is 110b. Use the following code to set port zero to Analog HI-Z, from Strong, by first going to Resistive Pull Down.

```
PRT0DM0 = 0x00; // low bits
PRT0DM1 = 0xff; // med bits
PRT0DM2 = 0xff; //high bits
```

6.1.2 Putting it All Together

The following code is a sample of a typical sleep preparation sequence for a 28-pin part. In this sequence, interrupts are disabled, the analog circuitry is turned off, all drive modes are set to Analog HI-Z, and interrupts are re-enabled.

```
void PSoC_Sleep(void){
    M8C_DisableGInt;
    ARF_CR &= 0xf8; // analog blocks Off
    ABF_CR0 &= 0xc3; // analog buffer off
    PRT0DM0 = 0x00; // port 0 drives
    PRT0DM1 = 0xff;
    PRT0DM2 = 0xff;
    PRT1DM0 = 0x00; // port 1 drives
    PRT1DM1 = 0xff;
    PRT1DM2 = 0xff;
    PRT2DM0 = 0x00; // port 2 drives
    PRT2DM1 = 0xff;
    PRT2DM2 = 0xff;
    M8C_EnableGInt;
    M8C_Sleep;
}
```

6.1.3 Sleep Mode Complications

The PSoC can exit sleep either from a reset or through an interrupt. There are three types of resets within the PSoC: External Reset, Watch Dog Reset, and Power On Reset. Any of these resets takes the PSoC out of sleep mode, and once the reset deasserts, the PSoC begins executing code starting at Boot.asm. Available interrupts to wake the PSoC are: Sleep Timer, Low Voltage Monitor, GPIO, Analog Column, and Asynchronous. Sleep mode complications arise when using interrupts to wake the PSoC or attempting digital communication while asleep. These considerations are discussed in detail in the following sections.

6.1.4 Pending Interrupts

If an interrupt is pending, enabled, and scheduled to take after a write to the SLEEP bit in the CPU_SCR0 register, the system will not go to sleep. The instruction still executes, but the PSoC does not set the SLEEP bit. Instead, the interrupt is serviced which effectively causes the PSoC to ignore the sleep instruction. To avoid this, interrupts should be globally disabled while sleep preparation occurs and then re-enabled just before writing the SLEEP bit.

6.1.5 Global Interrupt Enable

The Global Interrupt Enable register (CPU_F) need not to be enabled to wake the PSoC from interrupts. The only requirement to wake up from a Sleep by an interrupt is to use the correct interrupt mask within the INT_MSKx registers, as in the example below. If global interrupts are disabled, the ISR that wakes the PSoC is not executed but the PSoC still exits sleep mode.

In this case, you must manually clear the pending interrupt or enable global interrupts to allow the ISR to be serviced. Interrupts are cleared within the INT_CLRx registers.

```
//Set Mask for GPIO Interrupts
M8C_EnableIntMask(INT_MSK0, INT_MSK0_GPIO)
// Clear Pending GPIO Interrupt
INT_CLR0 &= 0x20;
```

6.2 Post Wakeup Execution Sequence

If the PSoC is awakened through a reset, then execution starts at the beginning of the boot code. If the PSoC is woken up by an interrupt service routine, the first instruction to execute is the one immediately following the sleep instruction. This is because the instruction immediately following the sleep instruction is prefetched before the PSoC is fully asleep. Therefore, if global interrupts are disabled, the instruction execution will continue where it left off before sleep was initiated.

6.2.1 PLL Mode Enabled

If PLL mode is enabled, the CPU frequency must be reduced to the minimum of 3 MHz before going to sleep. This is because the PLL always overshoots as it attempts to relock after the PSoC wakes up and is re-enabled. Additionally, you should wait 10 ms after wakeup before normal CPU operation commences to ensure proper execution. This

implies that ,to use sleep mode and the PLL, the software must be able to execute at 3 MHz. A simple write to the OSC_CR0 register can reduce CPU speed. However, this register just sets a divider of SYSCLK, which means that the CPU speed will vary between part families with different SYSCLKs. Typically, SYSCLK is 24 MHz

```
OSC_CR0 &= 0xf8; // CPU = 3 IMO = 24
```

6.2.2 Execution of Global Interrupt Enable

It is undesirable to get an interrupt on the instruction boundary of writing the SLEEP bit. This could cause all firmware preparations for going to sleep to be bypassed, if a sleep command is executed on a return from interrupt (reti) instruction. To prevent this, interrupts are temporarily disabled before sleep preparations and then re-enabled before going to sleep. Because of the timing of the Global Interrupt instruction, an interrupt cannot occur during the next instruction, which in this case is setting the SLEEP bit.

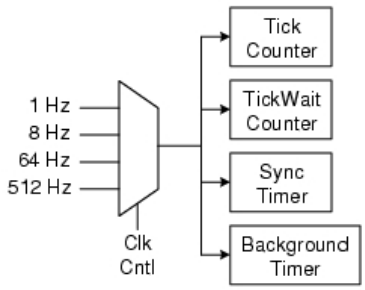
6.2.3 I^2C Slave with Sleep Mode

There are a few complications using an I^2C Slave in sleep mode. Because the IMO and CPU are shut off during sleep, there is no processing within the PSoC. The problem arises with the I^2C address. When an I2C START condition is sent to a particular address, the PSoC cannot process the address and therefore responds with a NAK. A typical workaround is to set up falling edge interrupts on either the clock or data lines of the I^2C bus. The master can then send a dummy START condition to wake up the PSoC. There is some lag time between waking up and being able to process an I^2C address, so the master may need to delay up to 200 µs before the next transmission or continue to send until an ACK is received. This solution has a second problem in that the PSoC will wake up on any I^2C falling edge traffic, which causes more total active time and higher sleep currents. Another solution is to use a third GPIO pin to wake up the PSoC and then send the initial START condition after the appropriate delay time.

6.2.4 Sleep Timer

The PSoC offers a sleep timer and a sleep timer user module. These are used while PSoC is asleep and both perform similar functions. The actual sleep timer runs off of the internal low-speed oscillator, which is never turned off. At selectable intervals of 1 Hz, 8 Hz, 64 Hz, and 512 Hz, the timer generates an interrupt. It is often useful to periodically wake the PSoC up to do some processing or check for activity. An example of this would be to periodically wake up to scan a sensor. The sleep timer user module uses the sleep timer to generate some additional functionality. This functionality includes a background tick counter to generate periodic interrupts, a delay function for program loops, a settable down counter, and a loop governor to control loop time. A simple block diagram for this functionality is shown below in Figure 6-1. .

Figure 6-1. Sleep Timer User Module Block Diagram



7. Resources

7.1 Website

Visit Cypress's CapSense Controllers website to access all of the reference material discussed in this section.

Find a variety of technical resources for the CapSense CY8C20xx6A/H family of devices at the CY8C20xx6A/H web page.

7.2 Datasheet

The datasheets for the CapSense CY8C20XX6A/H family of devices are available at www.cypress.com.

- CY8C20x36A, CY8C20x46A, CY8C20x66A, CY8C20x96A
- CY8C20336H, CY8C20446A

7.3 Technical Reference Manual

Cypress has created the following technical reference manual to provide quick and easy access to information on CapSense controller functionality, including top-level architectural diagrams, register summaries and timing diagrams.

- PSoC® CY8C20x66, CY8C20x66A, CY8C20x46/96, CY8C20x46A/96A, CY8C20x36, CY8C20x36A Technical Reference Manual (TRM)

7.4 Development Kits

7.4.1 Universal CapSense Controller Kit

Universal CapSense Controller Kits feature predefined control circuitry and plug-in hardware to make prototyping and debugging easy. Programming and I^2C-to-USB Bridge hardware are including for tuning and data acquisition

- CY3280-20xx6 Universal CapSense Controller

7.4.2 Universal CapSense Module Boards

7.4.2.1 Simple Button Module Board

The CY3280-BSM Simple Button Module consists of ten CapSense buttons and ten LEDs. This module connects to any CY3280 Universal CapSense Controller Board

7.4.2.2 Matrix Button Module Board

The CY3280-BMM Matrix Button Module consists of eight LEDs and eight CapSense sensors organized in a 4×4 matrix format to form 16 physical buttons. This module connects to any CY3280 Universal CapSense Controller Board.

7.4.2.3 Linear Slider Module Board

The CY3280-SLM Linear Slider Module consists of five CapSense buttons, one linear slider (with ten sensors), and five LEDs. This module connects to any CY3280 Universal CapSense Controller Board.

7.4.2.4 Radial Slider Module Board

The CY3280-SRM Radial Slider Module consists of four CapSense buttons, one radial slider (with ten sensors), and four LEDs. This module connects to any CY3280 Universal CapSense Controller Board

7.4.2.5 Universal CapSense Prototyping Module

The CY3280-BBM Universal CapSense Prototyping Module provides access to every signal routed to the 44-pin connector on the attached controller boards. The Prototyping Module board is used in conjunction with a Universal CapSense Controller board to implement additional functionality that is not part of the other single-purpose Universal CapSense Module boards

7.4.3 In-Circuit Emulation (ICE) Kits

The ICE pod provides the interconnection between the CY3215-DK In-Circuit Emulator and the target PSoC device in a prototype system or PCB via package-specific pod feet, using a flex cable. The following Pods are available.

- CY3250-20246QFN In-Circuit Emulation (ICE) Pod Kit for Debugging CY8C20236/46A CapSense PSoC Devices
- CY3250-20346QFN In-Circuit Emulation (ICE) Pod Kit for Debugging CY8C20336/346A CapSense PSoC Devices
- CY3250-20666QFN In-Circuit Emulation (ICE) Pod Kit for Debugging CY8C20636/646/666A CapSense PSoC Devices
- CY3250-20566 In-Circuit Emulation (ICE) Pod Kit for Debugging CY8C20536/546/566A CapSense PSoC Devices

7.5 PSoC Programmer

PSoC Programmer is a flexible, integrated programming application for programming PSoC devices. It can be used with PSoC Designer and PSoC Creator to program any design onto a PSoC device.

PSoC Programmer provides the user a hardware layer with APIs to design specific applications utilizing the programmers and bridge devices. The PSoC Programmer hardware layer is fully detailed in the COM guide documentation as well as example code across the following languages: C#, C, Perl, and Python.

7.6 Multi-Chart

Multi-Chart is a simple PC tool for real-time CapSense data viewing and logging. The application allows you to view data from up to 48 sensors, save and print charts, and save data for later analysis in a spreadsheet.

7.7 PSoC Designer

Cypress offers an exclusive Integrated Design Environment, PSoC Designer. With PSoC Designer you can configure analog and digital blocks, develop firmware, and tune your design. Applications are developed in a drag-and-drop design environment using a library of precharacterized analog and digital functions, including CapSense.
PSoC Designer comes with a built-in C compiler and an embedded programmer. A pro compiler is available for complex designs.

7.8 Code Examples

Cypress offers a large collection of code examples to get your design up and running fast.

- CapSense Buttons using SmartSense™ on CY8C20xx6A
- CapSense Buttons and Slider using SmartSense™ on CY8C20xx6A
- CapSense Matrix Buttons using SmartSense™ on CY8C20xx6A
- Reduced Power Consumption with CapSense CSD on CY8C20xx6A
- Reduced Power Consumption with CapSense CSA on CY8C20xx6A
- CSD Software Filter Examples
- CapSense® Sigma Delta (CSD) with LED Backlight Fading on CY8C20xx6A
- CSA with LED Backlight Fading on CY8C20xx6A
- CSD with TX8SW on CY8C20xx6A

7.9 Design Support

Cypress has a variety of design support channels to ensure the success of your CapSense solutions.

- Knowledge Based Articles – Browse technical articles by product family or perform a search on various CapSense topics.
- CapSense Application Notes – Refer to a wide variety of application notes built on information presented in this document.
- White Papers – Learn about advanced capacitive-touch interface topics.
- Cypress Developer Community – Connect with the Cypress technical community and exchange information.
- CapSense Product Selector Guide – See the complete product offering of Cypress's CapSense product line.
- Video Library – Quickly get up to speed with tutorial videos
- Quality & Reliability – Cypress is committed to complete customer satisfaction. At our Quality website you can find reliability and product qualification reports.
- Technical Support – World class technical support is available on-line.